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The National Space Program

It has been the custom of the Society for a number of years to invite a distinguished guest to the Fall Convention to address the Convention on Awards Night on some phase of engineering, not necessarily directly concerned with motion pictures or television, but of great general interest. In view of the rapid expansion of photographic instrumentation in space technology it seemed particularly apropos that Edgar M. Cortright, Chief of Advanced Technology Programs of the National Aeronautics Space Administration, be invited to address the 1959 Fall Convention. Mr. Cortright's talk on the National Space Program proved of such wide interest and the developments he described are so important that it has been decided to publish the major part of his address in order that it may be read by those who could not hear him and also for documentation for future reference.—Glenn E. Matthews, *Editorial Vice-President.*

When the National Aeronautics and Space Administration was established in 1958 it was the intent of Congress and the Administration that this country should have a broad and vigorous Space Program dedicated to the exploration and exploitation of space. The work of NASA did not start from scratch; we inherited a rich legacy of accomplishment on the part of science, industry and government; and on this foundation we have attempted to build a continuing and far-reaching program.

There have been both successes and failures during the past year. It is particularly important that we, in this country, view these incidents in their proper perspective. That is, we must take a long-range view of the Space Program and should not be overly elated with temporary successes or overly discouraged with temporary failures. On the other hand it would be dangerous to concentrate on and become preoccupied with only the goals which lie decades away. The proverbial donkey will not indefinitely pull a heavy load over a rough road in pursuit of a carrot which he never reaches. If he is allowed to bask in the oases along the way, reached by dint of his hard labors, the chances are he will keep going, enjoy the trip, and maybe get the carrot after all. So I think it is with all of us. We must look at the entire program as a continuing program in all of its aspects. I feel sincerely that the exploration of space will be an exhilarating experience, both for the nation and for each of us as individuals.

The Space Program is very broad; this brief discussion will be limited to the following areas: Space Sciences; Satellite Applications; Manned Space Flight; Propulsion and Booster Systems; and Advanced Technology.

SPACE SCIENCES

Atmospheres

Let us begin by taking a quick look at the study of the atmosphere surrounding our Earth. We know that we live at the bottom of a sea of air, which exerts approximately one ton of pressure on every square foot beneath it. During the ten years preceding the International Geophysical Year, this country fired about 400 sounding rockets up into the atmosphere to various altitudes, and during the International Geophysical Year we fired 200 more. The atmospheres program is now reaching the point where we're getting considerable scientific pay-off and this work will continue with increasing activity. From the use of these sounding rockets, plus more conventional meteorological efforts, we now understand quite a bit about the atmosphere up to about 50 to 100 miles above the Earth's surface. Within this atmosphere there is a great deal of motion resulting in what we call "weather." The motion of the atmosphere results primarily from the movement of the Earth plus the uneven distribution of energy (heat) which is fed into the atmosphere from the Sun (Fig. 1). Some of this radiation is absorbed, some is re-radiated, and some is scattered and reflected by the atmosphere. At the higher altitudes the products in the atmosphere begin to change; oxygen dissociates into atomic oxygen, and ozone becomes more prevalent, for example. Interactions of these rarefied gases with the radiations from the Sun are believed to be important, perhaps influencing or "telegraphing" some aspects of the weather.

Ionospheres

At an altitude of 100 miles there is only one-billionth of the atmospheric density that we have at sea level and yet above these altitudes is found much of the ionosphere. Let us examine the ionospheres program (Fig. 2). The old picture of the "ionosphere" was something like the following: it was believed to consist of discrete layers of charged particles — ions — the D layer at 35 miles, the E layer at 60, F-1 at 120 and F-2 at 180. These layers have some interesting properties: for one thing, depending on the wavelength of the radio waves which encounter them, they turn back the radio signals; for example, longwave radio is reflected from the lower levels of the ionosphere, the D or E layer, and the shortwave radio, which gets a longer range, is reflected from the F layers. Very-high-frequency radiation, such as is used for television transmission, penetrates all of the layers of the ionosphere. Because of this characteristic, the higher frequencies are used to communicate with space vehicles. During the night, the lower (D) layer disappears, the E layer becomes spotty, and the F layers merge.

As a result of some of the studies conducted during the International Geophysical Year, it was found that the ionosphere does not consist of four discrete layers, but is rather a continuous but varying distribution of ions. The ionosphere itself is gen-

This report was prepared by editing the transcript of a lecture given on October 6, 1959, at the Society's Convention in New York, by Edgar M. Cortright, Chief of Advanced Technology Programs, National Aeronautics Space Administration, 1520 H St., N.W., Washington 25, D.C.

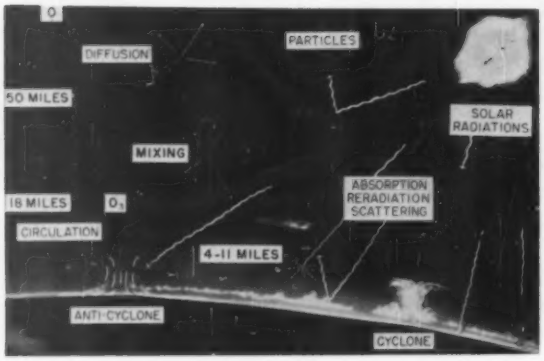


Fig. 1. Atmospheres.

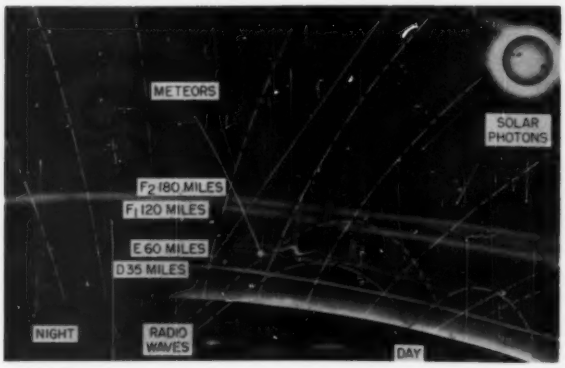


Fig. 2. Ionospheres.

erated by radiations from the Sun, primarily by ultraviolet radiations, but during the IGY we have found that x-radiation plays a part, at least in determining the density at the lower layers of the ionosphere. These studies are of continuing importance, not only to worldwide communication, but to the Space Program. Considerable additional work is planned for the development of vertical sounding rockets, and of earth satellites; some, which we call 'topside sounders," beam radio signals down through the ionosphere.

Energetic Particles

Among the areas of study of radiation from outer space is that of "energetic particles" (Fig. 3). The energetic particles in space which we have been longest concerned about are cosmic rays. These very-high-frequency particles approach the Earth uniformly from all directions. They are the most energetic particles known, their energies being orders of magnitude higher than can be generated under laboratory conditions. In their collisions with the atmosphere, they generate secondary radiations which may be different from any that can be generated on the Earth, and the study of which is important to fundamental particle and nuclear physics.

Another type of particle radiation under study is that encountered in what is now called the "great radiation belt," discovered primarily through the efforts of Van Allen. The discovery was not anticipated, but was one of the typical bonuses that often occur in scientific research. This radiation belt was at one time thought to consist of a single, doughnut-shaped belt around the Earth. The particles in the belt are protons and electrons but we don't know the energy distribution or the quantitative apportionment between the protons and electrons or even for certain where they come from. Being charged, the particles are entrapped by the Earth's magnetic field where they circle around magnetic lines of force and oscillate back and forth between the poles as described by magneto-hydrodynamical laws.

Recent data obtained from the Explorer 6 "paddle-wheel" satellite, have revealed that the radiation intensity in the "belt" varies by orders of magnitude from week to week. It has been found that the radiation flux distribution through the belt is far different from anything that had been predicted; so we're just scratching the surface of our understanding of this radiation belt.

Fields

Another area of scientific endeavor of particular interest is that of fields (Fig. 4). Fields are generated by certain objects and are felt in some manner at distant points, but we don't know how or why; we have only empirical laws which describe their action. Of prime interest are magnetic, electric and gravitational fields. Within the Earth's atmosphere, between the Earth and the ionosphere, is a powerful electric field, 290,000 volts potential difference; with the aid of vertical sounding rockets we are endeavoring to understand its significance. We also want to understand the interactions of the fluctuations in the Earth's magnetic field with ionospheric variations and variations in the radiation belt. The Earth's magnetic field is represented in Fig. 4 by lines of force which resemble closely a classical dipole field. For years it has been known that this field varies with time; the magnetic pole moves. The theory most often accepted is that this field is generated by a movement of a fluid core within the earth. Some of the fluctuations are more rapid than might be expected from this huge, slowly circulating mass inside the earth and we are beginning to believe that these fluctuations are associated with movement and density changes of the charged particles trapped in the great radiation belt.

One of our fondest hopes is that by these studies we shall contribute to the basic understanding of field theory and hence to fundamental science in all categories. For example, one of the

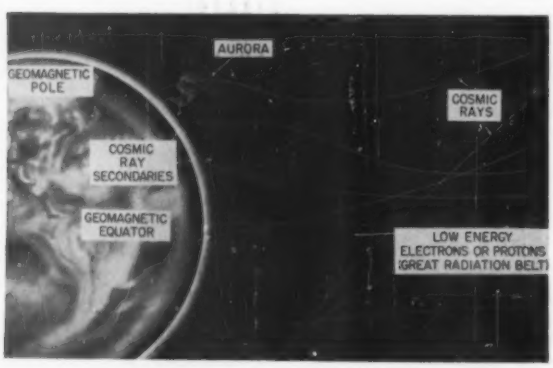


Fig. 3. Energetic particles.

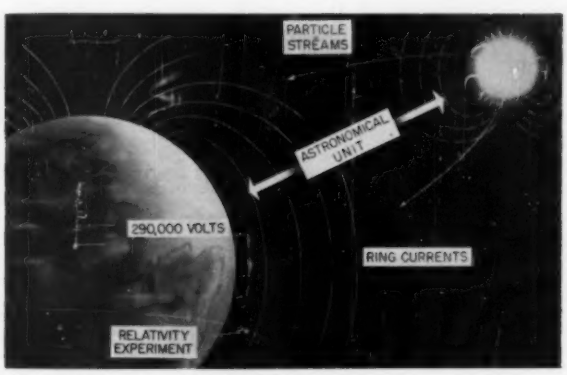


Fig. 4. Magnetism, electricity, gravity.

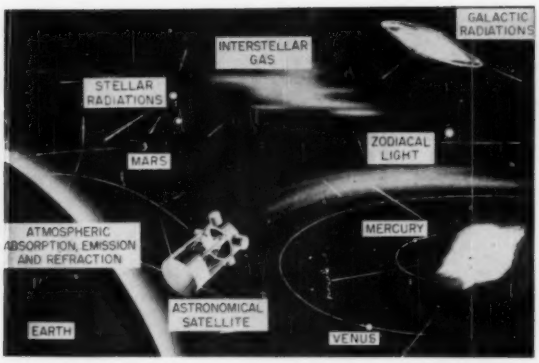


Fig. 5. Astronomy.

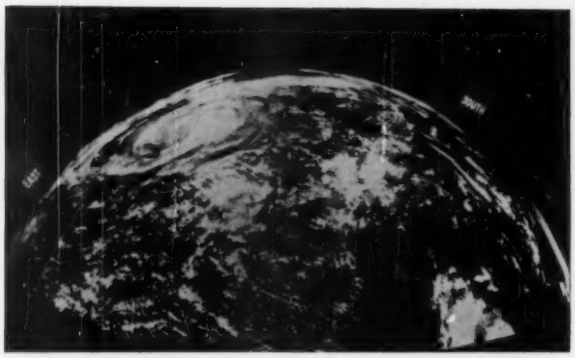


Fig. 6. Cloud cover and storm detection.

world's most distinguished scientists, the late Albert Einstein formulated a general theory of relativity, in which he attempted to relate these fields. This relationship has not yet been established. If the general theory of relativity is accepted, it would follow that gravitational attraction has an effect on the rate of physical processes, it slows them down; then if we remove gravitational attractions these processes should speed up.

We now have a uniqie opportunity to test this theory. The technique would be as follows: we would put a satellite containing an atomic clock into orbit. This clock would be accurate to, at least, one part in one billion. On the Earth we would have a matching clock, which would be synchronized with the orbiting clock, which would orbit at about 6000 miles altitude. The two clocks would be kept running over a long period of time and then compared.

Astronomy

Astronomy has many facets. The astronomer is interested in observing incoming electromagnetic radiations in the complete spectrum — all the way from radio frequencies up through infrared, ultraviolet, x-ray, and even gamma radiation (Fig. 5). These different radiations tell us different things. By watching the radio frequencies, the radio astronomer can gather data on galaxies and nebulae. By watching the frequencies in the infrared range where molecules radiate, the astronomer may detect something about life processes on distant planets; and by measuring x-radiation and gamma radiation, he can detect facts about constituents of far-distant space. Needless to say, a prime goal, and one of the most exciting, is the possible discovery of some form of life beyond the confines of the Earth. To conduct this program scientists are working on orbiting telescopes to study these objects in space. A special orbiting telescope is being developed to study the Sun.

Exploration of Nearby Celestial Bodies

The areas of interest in the space sciences program — atmospheres, ionospheres, particles and fields — have been illustrated with somewhat of an Earth-oriented viewpoint. Even astronomy was depicted as using instruments in Earth satellites. Actually, a major segment of the space sciences program is currently devoted to sending instrumented probes to our near neighbors in the solar system, the Moon, Mars and Venus. These probes will make measurements pertinent to all of the areas of scientific interest already discussed, and in addition, geophysical measurements of the surface and subsurface characteristics of these bodies will be made.

An evolutionary sequence of instrumented spacecraft will be required which will proceed through missions such as fly-bys, impacts, orbits, rough landings and soft landings.

One day man will follow, with the Moon as the first likely goal. Let us not be deluded, however; the task of returning a man safely from the lunar surface is fantastically difficult from an engineering viewpoint. It is not just "just around the corner."

SATELLITE APPLICATIONS

Another phase of the Space Program is Satellite Applications. For those of a practical bent who like to see early, practical returns, there are a number of applications which stand to benefit greatly from the use of the Earth satellite. These applications include meteorology, communications, navigation and geodesy. I will limit my discussion tonight to a review of meteorology and communications.

Meteorological Satellites

Now, for the first time, the meteorologist has an observing platform equal in scope to the problem which faces him, namely observation of all of the world's weather, all of the time. The satellite has another advantage. By virtue of its position above the atmosphere, it can make certain types of measurements which can be made in no other way. The first inkling of what the satellite might do for the meteorologist came in 1954 with a rocket fired from White Sands, N.M. Montage photographs (Fig. 6) were made from films taken at 100 miles altitude. Clearly shown is a vortex pattern of clouds building up over the Gulf Coast of Texas. This is described by the meteorologist as a relatively small-scale cyclonic disturbance, although hundreds of miles across, and it was undetected by even the relatively numerous observing stations of the conventional weather network. This can happen, not because Weather Bureau observers are not careful and diligent in pursuing their observations, but because of the difficulty of piecing scattered observations together into a sensible whole. The rocket picture showed this storm very clearly. Later, the storm turned out to be relatively severe, causing heavy rain damage in the Mississippi valley.

Figure 7 illustrates other types of measurements that can be made with the satellite to help the meteorologist. The use of radar gives hope of determining the heights of the clouds, the different layers (stratification), and even precipitation areas throughout the world. Thunderstorms perhaps can be located by use of spherics (detection of lightning flashes). A type of experiment known as the "heat budget" experiment essentially measures the local imbalance of radiation between incoming solar, reflected solar and re-radiated energy. It is this local imbalance which drives the heat pump which moves the large air masses over the surface of the earth and causes what we know as "weather."

We also have hopes, by using spectrometers, of determining some of the temperatures in the atmosphere, as well as some of the constituents. Of particular interest to engineers are the types of instruments being used. Our only tie to the earth is electromagnetic radiations, and hence we plan to use all of them that we know how to use. Included are television, infrared detectors, photocells, radar and spectrometers.

Our earliest meteorological satellites will be spin-stabilized, and as a result will get to "look" at the Earth only during a fraction of their orbital period. They will carry daylight television and rudimentary infrared equipment. Our goal, however, is to

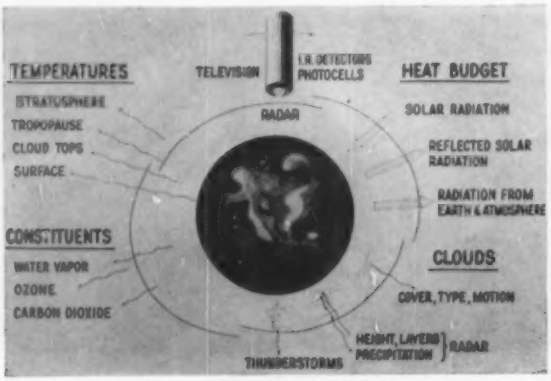


Fig. 7. Measurements with meteorological satellites.

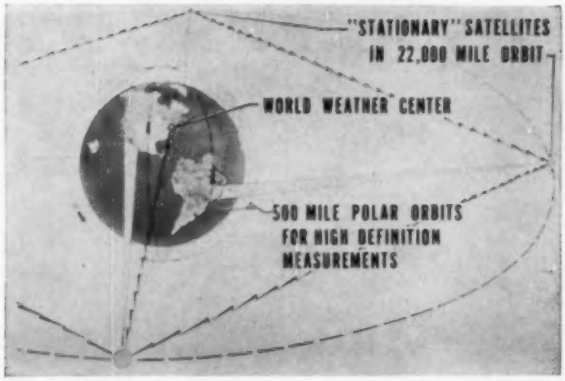

"STATIONARY" SATELLITES IN 22,000 MILE ORBIT
WORLD WEATHER CENTER
500 MILE POLAR ORBITS FOR HIGH DEFINITION MEASUREMENTS

Fig. 8. Meteorological satellites.

make possible by adequate research and development, the working elements of the hypothetical system visualized in Fig. 8.

One element of this system is an Earth-oriented satellite with three-axis stabilization in a relatively low altitude polar orbit. By using a number of them, any one portion of the Earth, rotating beneath these orbits, would be viewed with not more than a few hours lapse between successive observations. These low-altitude satellites would obtain a detailed type of information. High-altitude satellites can be placed at 22,300 miles above the equator. At this position they will go around the Earth once each day — and hence will stay directly above a suborbital point on the Earth's equator. By remote-control television the ground weather observer could select interesting weather situations almost anywhere on Earth and watch them develop. How many and what type of satellite will actually be needed remain to be seen.

One of the main problems with a system like this is getting the data back to a weather center on a real-time basis. Data from just one satellite on the other side of the world would swamp existing transatlantic communications. At present there is a capacity of less than 200 telephone channels across the Atlantic; and yet one television channel is equivalent in bandwidth to 1000 telephone channels.

Satellites for Communication

Meteorological satellites would be only one type of equipment requiring a communication bandwidth of video magnitude. We also want transatlantic video for its own sake. It is more than likely that in the near future the cables will be saturated by voice communication alone, without giving us any transatlantic TV.

Among other approaches to transatlantic TV, the communications satellite is one of the most promising. Leading communications organizations seem to support this point of view. Two types are of particular interest to NASA at the present time; one is the passive communications satellite shown in Fig. 9. Communication is accomplished by a high-intensity signal transmitted toward a reflecting surface which is in orbit about the Earth. A 100-ft balloon will be used in the first experiment. Signals are reflected omnidirectionally — that is in all directions — and they thus cover a large area of the Earth, but they are very weak. By listening for these signals with very sensitive equipment on the ground, a communication link of high bandwidth can be completed. It can be calculated that even at 3000 miles altitude with a sphere of this size we can get a television bandwidth across the Atlantic Ocean.

This first experimental step in this direction is called Project Echo. This experiment will utilize a 100-ft balloon made of aluminized Mylar only 2/1000 in. thick. The balloon weighs only about 150 lb despite its huge diameter. The reflecting experiments will be conducted between the Jet Propulsion Laboratory's 85-ft antennae in California and antennae of Bell Telephone Labs. and the Naval Research Laboratory on the

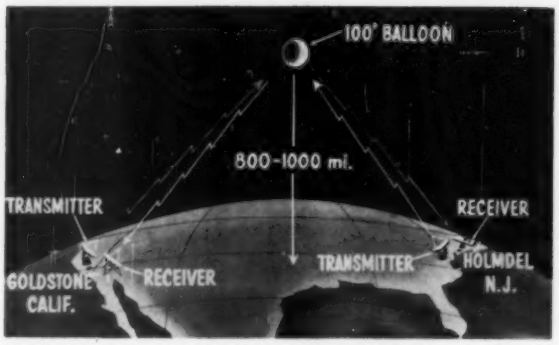


Fig. 9. Passive communications satellite experiment.

East Coast. It is hoped that other experimenters who have suitable equipment will join in the experiment.

Figure 10 shows the balloon inflated in a hangar. Its size can be compared with the height of two men standing before it. This package can be deflated to a sphere only 30 in. in diameter. There are problems: for example, how to inflate the fragile balloon without tearing it; also, there is no way of knowing how long this balloon will stay inflated. This would depend on how rapidly it would be perforated by micrometeorites. It is inflated with entrapped gases and also water vapor. Another problem is that of finding the balloon and keeping track of it. A beacon is being developed to be cemented to the skin of the satellite and so facilitate locating it.

The reflecting satellite has this one big advantage; it has no equipment on board to deteriorate over a period of time. If the surface is made rigid it should remain usable for very long periods of time. A world-wide commercial system might need as many as 30 such satellites. Keeping track of them is going to be difficult, and switching from one to another, without breaking the television program right in the midst of the all-important commercial, is an engineering problem, but one which can certainly be worked out.

Another type of communications satellite is the "active repeater" (Fig. 11). This system does not use a passive reflective surface in orbit. The active repeater type has some advantages but also some disadvantages. These satellites would be in the magic 24-hr orbit over the equator, three of them equally spaced, maintaining station and pointed towards the Earth. The technique of communicating to the other side of the Earth would be as follows: the originating station broadcasts to the satellite with very-high-frequency radio communication, it is repeated (transponded) back to the Earth to another antenna, then up to another satellite and back to the Earth and the link is complete.

Video bandwidths are certainly possible but satellites of this type will be relatively heavy, 800 to 3000 lb; they may or may

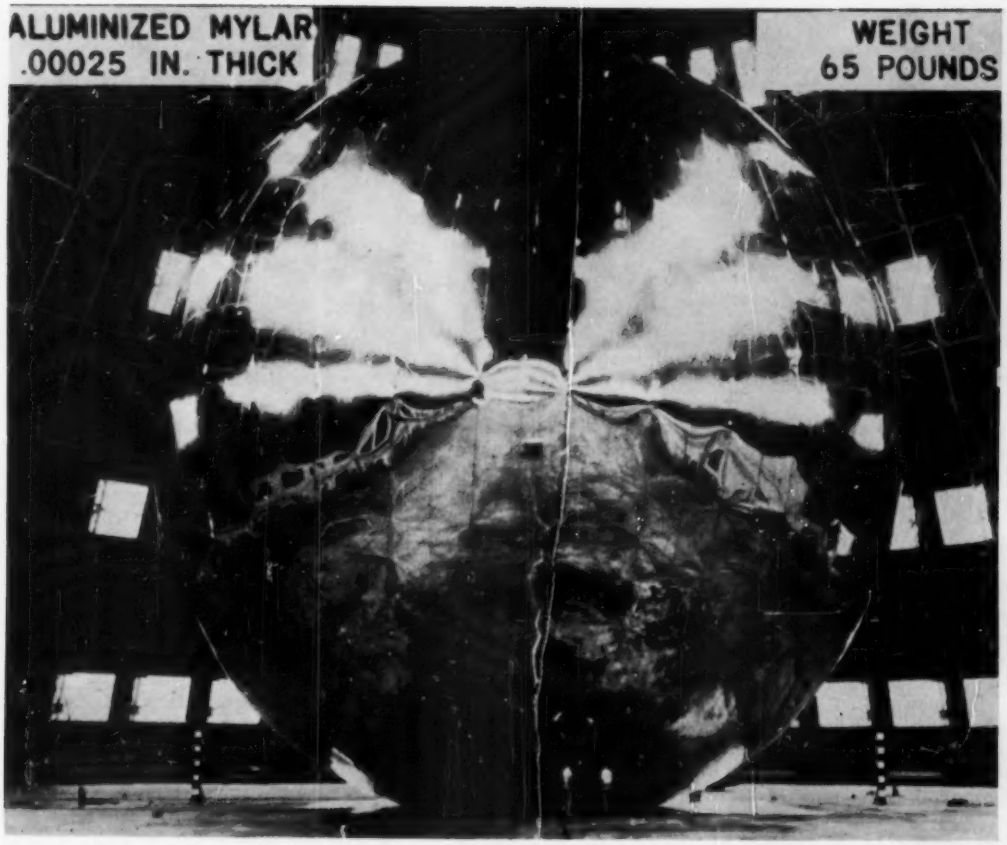


Fig. 10. One-hundred-foot diameter inflatable satellite.

not be able to get by with solar power alone. Electronic reliability will, of course, be at a premium.

To round out briefly the discussion of satellite applications I must at least mention navigation and geodetic satellites. Navigational satellites give us the opportunity of all-weather navigation on the ocean with accuracies of a mile or better, and hence are of interest to us. Geodetic satellites enable us to tie together for the first time, the detailed mapping network between the U. S. (North American Continent) and Europe. This country has not been able to make that tie, so in order to improve the accuracy it seems desirable to use the geodetic satellite. From a scientific point of view there are important implications in the accurate determination of the detailed shape of the Earth (which is not spherical nor elliptical, but slightly in the shape of a pear) and also in the determination of the gravitational anomalies within the Earth's crust. This information will have important implications for studies of the structure of the Earth and its formation.

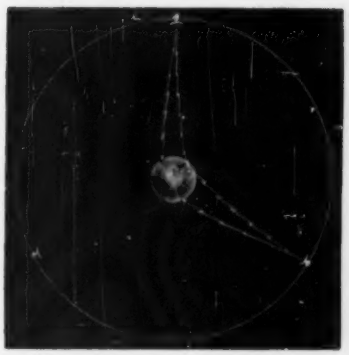


Fig. 11. Active repeater—24-hr orbit.

Satellite Characteristics	
Weight	800–3000 lb
Power supply	Solar cells or reactor
Life	2–3 yr.
Orbit	22,300-mile altitude equatorial
Antennas	Directional attitude stabilized

MANNED SPACE FLIGHT

The next area of discussion is Man's flight into Space. This area has received the most public attention and, in fact, Project Mercury, designed to put man into orbital flight around the Earth, is top priority program within NASA. The overall program of man's space flight encompasses considerably more than Project Mercury. Actually it begins before Mercury with the X-15, which is designed to go several thousand miles per hour to altitudes in excess of 100 miles, and extends beyond Mercury to orbiting laboratories and lunar flight.

Some day it is likely that we will be able to land on the Moon a man with scientific instruments, but realistic planners do not hold out great hope for doing this within the near future. Interplanetary flight is even more visionary; we study it, we plan for it; we conduct research in that area, but you may believe that this is in the far-distant future. Project Mercury is what we have now, and it is exciting enough in its own right.

Figure 12 shows the Project Mercury ballistic capsule. It is relatively small and as simple and light as possible. It has a carefully chosen shape with the blunt face forward to create a very high drag configuration. In this way the kinetic energy of the satellite, in re-entering the Earth's atmosphere with velocities of 25,000 ft/sec will be dissipated in the form of pressure drag rather than friction drag. If this were a very slender, streamlined body, the only way it could slow down to a respectable velocity is by skin friction, which generates heat and would rapidly burn it up. We have discovered that this shape can survive.

Recently we had a successful "Big Joe" shot with one of these on top of an Atlas. A malfunction of the Atlas caused the vehicle

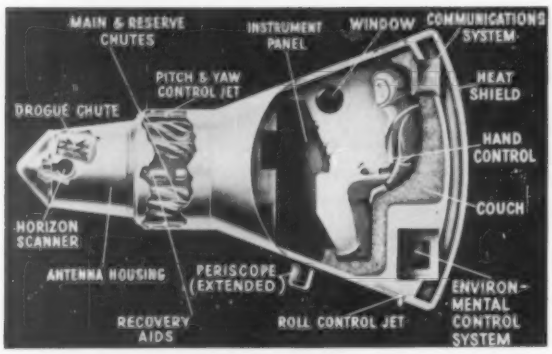


Fig. 12. Project Mercury ballistic capsule.

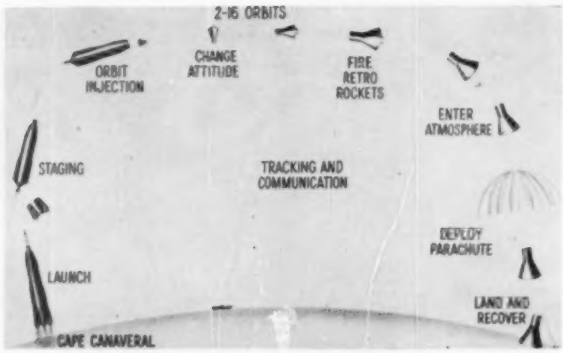


Fig. 13. Project Mercury flight trajectory.

to come in with a high angle of attack resulting in a high-amplitude oscillation; but nevertheless it survived the most severe re-entry any vehicle has yet survived. The damage was nominal and almost exactly that which could be predicted theoretically, so we were very encouraged. A man could have survived that flight.

The astronaut will be seated in a couch which cushions him from the accelerations of 8 times gravity (8 g) which he experiences during launch and re-entry. In an extreme emergency maneuver, such as failure of the booster somewhere during the launching trajectory, he could experience as high as 18-g deceleration, but could still come through no worse for wear.

The pilot will not merely go along for the ride. He can do things such as monitoring instruments, navigation, retrorocket ignition and controlling the attitude of the vehicle. Although the vehicle is stable during most of the re-entry, it is not stable for the entire speed range and must have automatic stabilization to damp the oscillations. The pilot is a back-up to this equipment; that is, he can override it or countermand its automatic decisions if he so chooses. When a vehicle gets down to about Mach-1 or the speed of sound, a drogue parachute opens to damp the oscillations which occur there, since the vehicle is not stable at that speed. Later one of two parachutes opens and lowers the man into the ocean where he awaits pickup.

Incidentally, during the "Big Joe" shot the capsule was picked up several hundred miles short of its goal; this was an emergency situation and there was virtually no delay in getting it.

Figure 13 indicates the launching trajectory. The capsule sits on top of an Atlas vehicle, and on top of the capsule is a set of emergency escape rockets. If something goes wrong during boost, these emergency rockets can be used to carry the capsule clear of the Atlas. The parachutes would then deploy and lower the man to Earth safely. This will even work in the event of a detonating-type explosion on the pad, which is one of the most hazardous situations that could occur. Another emergency could occur right after second-stage burnout, or just before that if the man did not reach orbital velocity and had to come back in on somewhat of a ballistic trajectory, which is a very-high-deceleration trajectory. But he will be able to survive that also.

In orbit, the capsule turns over face forward and is attitude-controlled during the flight. It will travel around the earth two to three times, according to plan, and somewhere between Hawaii and the West Coast the retrorockets will be fired. They will slow the satellite down (by approximately 500 ft/sec as I recall) and the satellite will begin a gradual descent, will re-enter the Earth's atmosphere over the United States, and will descend to the ocean in the area of the Atlantic Missile Range.

Figure 14 shows the probable trajectories. The launch is eastward, over Africa. Tracking and communications stations are located all around the world, either in the form of ships at sea or land-based stations: Africa, Indian Ocean, Australia, Far Pacific, Hawaii, West Coast, East Coast, Bermuda, Atlantic Ocean. Because the Earth rotates under the orbit, the orbit appears to shift to the westward, during each orbit, and on the third orbit the man is in position to come down in the recovery area of the Atlantic Missile Range.

Figure 15 shows the three booster vehicles used in the Mercury program. Little Joe is designed to give the vehicle approximately 4000 miles per hour, and tests out the capsule itself under maximum dynamic pressure conditions. The Redstone will be the first vehicle on which a man could fly, enabling a test of

Fig. 14. Project Mercury orbital flight paths.

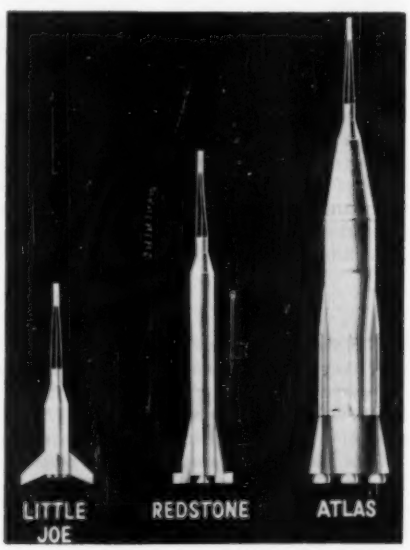
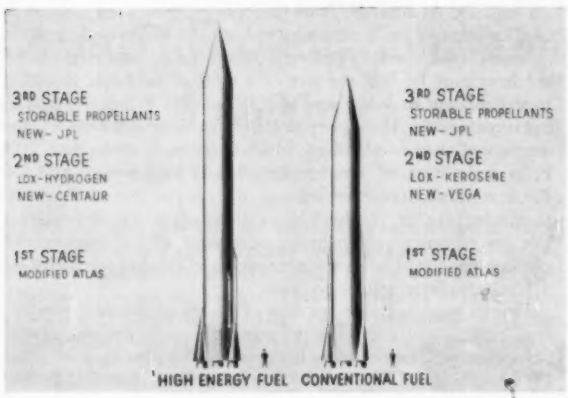
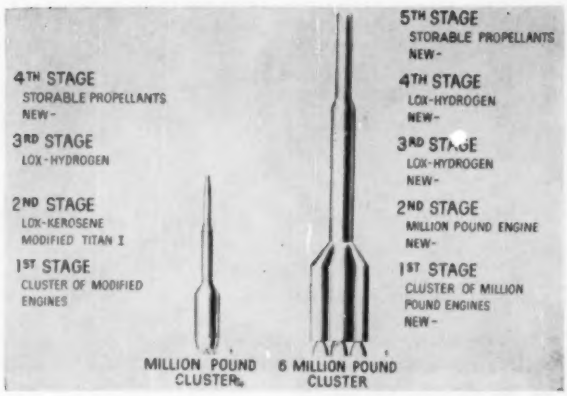


Fig. 15. Project Mercury rocket flight test vehicles.





Figs. 16A and B. Advanced boosters.

man and vehicle mated together on something less than orbital velocity. The Atlas is the only vehicle capable of putting this capsule into orbit and it will test out the MacDonnell capsule before a man ever goes in it. The 3-orbit mission will be accomplished with animals before it will be attempted with a man. We want to be sure that the man has the same probability of returning safely that he would have in flying any new type of experimental aircraft.

PROPULSION AND BOOSTER SYSTEMS

Propulsion and booster rockets are vitally important; a large percentage of the money which is being invested in the space program is going into improving our capabilities in this area. The vehicles we have been forced to use this past year have not been designed to do some of the jobs we'd like to do. The only one of these vehicles really designed to do an orbital mission was the much-maligned Vanguard rocket, which is the most sophisticated of all in terms of pounds of payload in orbit per pound of vehicle. It actually was expected to achieve one satellite in orbit and out of the series it achieved three, which I think is better than most people realize.

The Jupiter C, designed by the Army Ballistic Agency, used the Redstone and a cluster of solids; this was used to put our first satellite up. This system was improved by putting the solid package on top of a Jupiter rocket. The country achieved still better systems by putting the upper stages of the Vanguard rocket on top of the Thor and Atlas (The Able series) missiles. Even more successful and capable satellite boosters have been developed by the Air Force to launch the Discoverer satellites. These vehicles utilize a "Hustler" rocket in the second stage and give quite large payloads on top of the Thor and the Atlas (The Agena series).

Four vehicles are under consideration for the future Space Program. The first two are shown in Fig. 16. (The Vega vehicle on the right has been cancelled since the delivery of this talk and will be replaced by the Atlas Agena for some missions and the Centaur for others.) The Centaur is shown on the left side of Fig. 16A. The first stage is the same as that of the Vega, or a modified Atlas. A new second stage uses liquid hydrogen and oxygen, which gives a much higher specific impulse than conventional propellants. This system will have from 50 to 100% greater payload capability than the Vega and on it we base great hopes for the 1962–1965 period.

Figure 16B shows even more advanced systems — one is the Saturn rocket being developed by the Army Ballistic Missile Agency. This system utilizes a cluster of eight ICBM-type engines which give in excess of a million pounds of thrust. The second stage has been conceived of as a modified Titan ICBM. The third stage hopefully will use liquid oxygen (LOX) and hydrogen and the fourth stage will be new. This vehicle has greatly increased capability. I am not at liberty to discuss payloads of this vehicle but you can pretty much scale up payloads in proportion with the initial thrust, so this may carry four times as much payload as the Centaur.

NASA has contracted with Rocketdyne to develop a 1 million- to 1½-million-pound-thrust single-rocket engine using conventional fuel. This large engine is envisioned for clustering into a system of four or more first-stage engines. This gigantic vehicle would have on its second stage, a single million-pound-thrust engine; the third stage would use a new LOX-hydrogen engine; the fourth stage, a new LOX-hydrogen engine, and the fifth stage would also be a new engine. This vehicle will take years to develop, will be a very expensive undertaking and hence will be the subject of considerable review. But this vehicle would be the first one which could land two men on the Moon and bring them back without staging in orbit. To accomplish this mission with a vehicle of the million-pound size would require multiple staging in Earth orbit before launching off into a flight to the Moon and return. Which technique will ultimately be used to best advantage is not yet clear.

ADVANCED TECHNOLOGY

I will conclude with a brief run-through of some of the more exotic systems which we've all heard about — so far I've been talking about fairly conventional, albeit large, rockets. I want to go on now and say a word about the nuclear rocket, electric propulsion systems and energy sources.

The nuclear rocket system is shown schematically in Fig. 17. It consists of a reactor with a fissionable material embedded in some material such as graphite or tungsten or some other high-temperature element. The fissioning material, by bombarding the containing material with the fission products, generates tremendous amounts of controlled heat. The heat is trans-

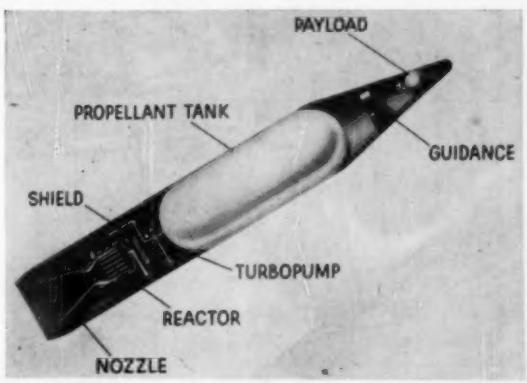


Fig. 17. Nuclear rocket components.

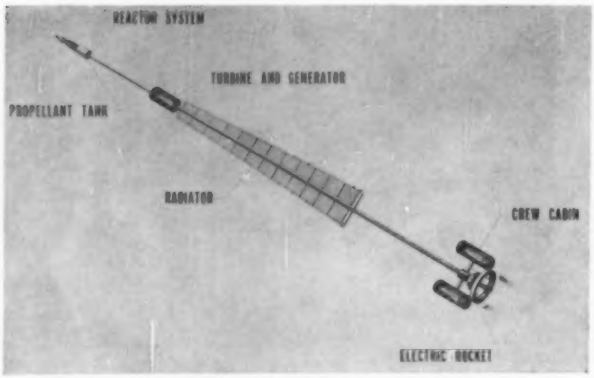


Fig. 18. Electric space vehicle.

ferred to the propellant (probably hydrogen) as the hydrogen flows through it, and the fuel elements are thus kept cool. The process of heating the hydrogen gives it tremendous velocity as it exits the nozzle. The efficiency of propellant utilization is directly proportional to the velocity of the exiting jet and the nuclear rocket can achieve payloads to Mars, for example, on the order of 5 times as great as the payload of a conventional chemical rocket for the same initial takeoff weight. This is the reason for our tremendous interest in this vehicle.

Another system — a competitor of the nuclear rocket in current advanced research and development, is shown in Fig. 18. This is the so-called electric propulsion system. With this system electricity may be generated with a reactor or with a solar heat source combined with a conventional boiler and turbo-electric generator. This electrical power will be used to accelerate either ions or plasmas to tremendous velocities, where specific impulses of 20,000 can be attained. However, there are large penalties which offset much of this advantage: they include the great weight of the reactor, the shielding, the electrical generating equipment, and the enormous radiator required to dissipate waste heat. At least 80% of the energy generated cannot be used because of cycle efficiency of both the turbo-cycle and the electrical equipment. The large, thin radiator used to get rid of the heat may be half the size of a football field (on this illustrated mission at least) and will be subject to penetration by micrometeorites. How do you detect these penetrations? How do you get close to a surface, which is certainly more than 1000 F, to make repairs? The combination of high weight and low thrust results in longer round-trip times to the planets than with the nuclear rocket. We don't know the answers to these problems. We are working now primarily on some of the fundamental physics associated with the generation of the high-velocity jet. There remains much to be done.

Energy sources is another area of advanced technology which is of great importance. Energy sources include nuclear, chemical and solar. The chemical battery is useful primarily for short-life applications. The weight necessary for a chemical battery increases in direct proportion to the amount of time it is to be used. Since there is a continuing requirement for long life for our satellites and probes chemical batteries are usually ruled out as the sole source of power. Solar power is currently one of the favorites. Solar cells convert sunlight into electrical energy. These cells are not always in the Sun, but are sometimes in the shadow of the Earth so solar cells are supplemented with batteries. Also of interest is the collection of solar energy by large mirrors which focus the radiant energy onto electrical generating equipment such as thermionic emitters, turbo-electric equipment, etc.

The nuclear systems become most attractive for relatively large amounts of power which would otherwise require huge mirror collectors or huge solar cell arrays. Because these situations will eventually face us, such equipment is under active development.

In attempting to review so many aspects of the National Space Program it has been necessary to treat some areas in too cursory a manner. For this I apologize. I conclude with the hope that each listener will find at least one facet of the program which will be stimulating and worthwhile to him.

Orbit Determination From Optical Tracking

By DOUGLAS DUKE

Experiences with data from optical tracking instrumentation at the Atlantic Missile Range have shown that excellent satellite orbit determinations can be obtained from such data. Results are exemplified by tracking data on passes of satellite 1958 delta one (Sputnik III rocket). Various methods of orbit determination are discussed and applications of some of the simpler methods are illustrated. For shortcomings found with existing equipment, specific improvements are recommended.

On Friday, October 2, 1959, there occurred a total eclipse of the Sun which was visible in the New England states, the North Atlantic, and North Central Africa. Figure 1 is a map of the path of totality and many of the other graphical features of the eclipse. It is noteworthy that the detailed mathematical computations concerning this eclipse were made at least two years ago. Table I shows the computed times and positional data involved with the event. One can see the accuracy to which the computations have been made. Although made two or three years in advance, these computations are accurate to about a second of time and a mile or two in the position of the Moon's shadow on the Earth. The effectiveness of these calculations demonstrates the power of the mathematical methods of computation available to the astronomer. In situations where only forces of gravitation are involved, it is possible to make highly accurate predictions of positions of celestial objects far into the future. These computations are based completely on the laws of motion and gravitation set down by Newton almost three centuries ago.

By properly calculating the gravitational attraction on an object by all other bodies which attract it significantly, one can determine the acceleration or change in velocity of the object, and hence, its future course. The eclipse calculations are an example of this. In this case the positions both of the Moon and the Earth relative to the Sun have to be predicted with great precision in order to determine where the shadow of the Moon will fall with respect to the Earth's surface. The fact that the Moon is significantly attracted both by the Earth and the Sun introduces complications quite severe in nature, necessitating much detailed calculation. This is an example of the famous 3-body problem which is very difficult mathematically. Another recent example of this is the lunar probe. During a considerable portion of its flight, a lunar probe would be simul-

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(This paper was received on October 16, 1959.)

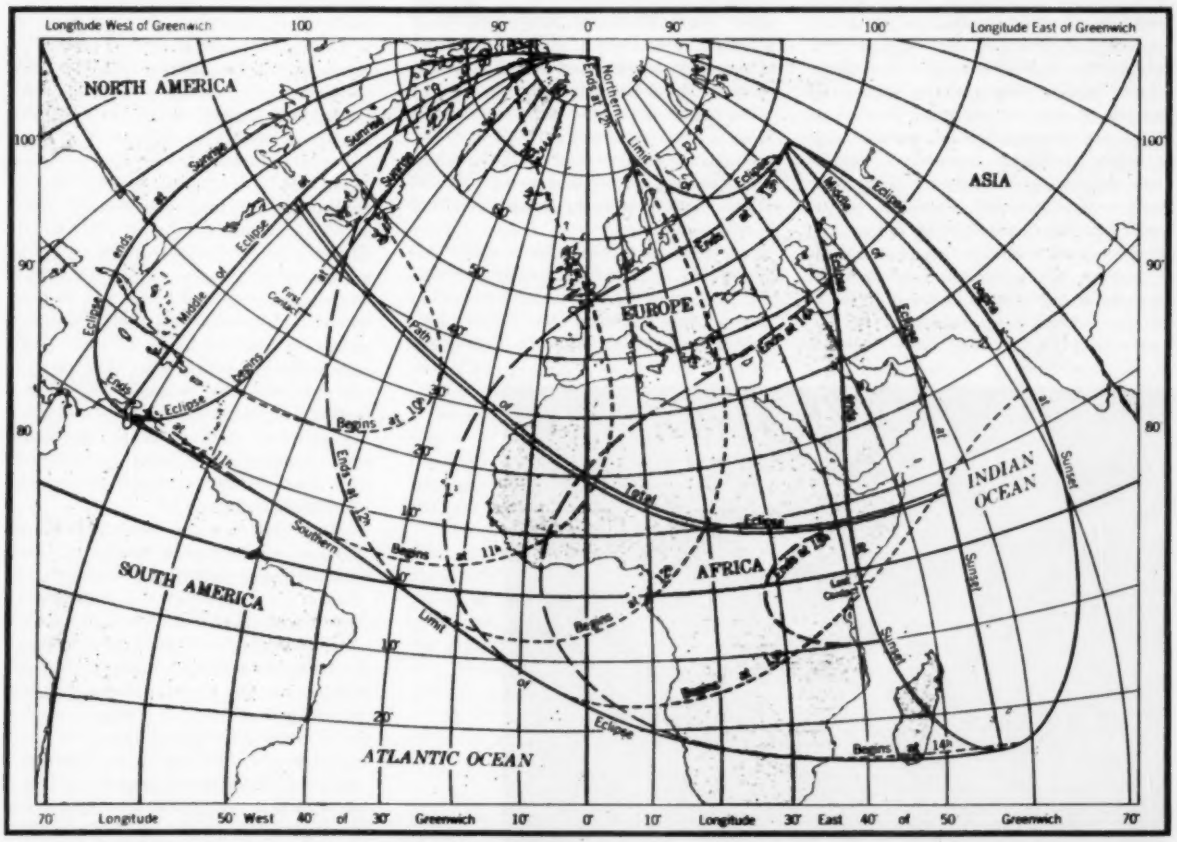

Fig. 1. Map of Path of Totality; total eclipse of October 2, 1959.

Table I. Computed Times and Positional Data for Total Eclipse of the Sun.*

Elements of the Eclipse

	day	hr	min	sec
Universal time of ☌ in right ascension, October	2	12	12	16.6

	hr	min	sec		sec	sec
Sun and Moon's R.A.	12	31	25.11	Hourly motions	9.06 and 137.54	
	°	′	″		′	″
Sun's declination	−3	23	28.1	Hourly motion	− 0	58.2
Moon's declination	−2	57	13.0	Hourly motion	−11	07.0
Sun's equa. hor. parallax			8.8	Sun's true semidiam.	15	58.8
Moon's equa. hor. parallax		59	38.8	Moon's true semidiam.	16	14.4

Circumstances of the Eclipse

	Universal Time			Longitude from Greenwich		Latitude	
	day	hr	min	°	′	°	′
Eclipse begins October	2	09	49.1	+57	40	+33	32
Central eclipse begins	2	10	50.3	+72	05	+42	35
Central eclipse at local apparent noon	2	12	12.3	+ 5	41	+22	57
Central eclipse ends	2	14	02.7	−56	16	+ 7	21
Eclipse ends	2	15	03.7	−41	33	− 1	44

* *American Ephemeris and Nautical Almanac for 1959*, U. S. Government publication, p. 311.

taneously attracted both by the Earth and the Moon, leading to the same 3-body problem.

The situation in which a small body is under the gravitational influence of a single, much heavier spherical body is much simpler mathematically. Manipulation of Newton's laws of motion and gravitation provides numerical relationships about the motion of the smaller body relative to the larger which will be true forever, assuming that only forces of gravitation are acting. For example, the orbit of the body will lie in a fixed plane which passes through the center of gravity of the attracting body, and its shape will be that of a conic section, that is, either an ellipse, parabola or hyperbola, depending upon the velocity of the body which is being attracted. In the case of planets and satellites, the path to be considered is always that of an ellipse.

Another derivable relationship states that the linear velocity of the body in its orbit is inversely proportional to its distance from the attracting body. It is also possible to derive a rather more involved relationship for the change of angular position within the orbit with time.

Finally, one can show that for a given amount of mass in the attracting body, there is a unique relationship between the distance of the orbiting body from the attracting body and its period of revolution about that body.

The above statements suffice to inform us as to what to expect in the general sense. Since there are many features in which elliptical orbits differ from each other, such as size and shape, there is still the problem of determining just what particular ellipse will be followed. It is therefore necessary to assign a unique set of orbit constants or orbital parameters (as they are shown) to a particular ellipse, setting it apart from any other possible ellipses.

To begin with: since the orbit lies in a plane (Fig. 2), it is necessary to designate the particular orbit plane with respect to the coordinate system. One way in which this could be done would be to consider

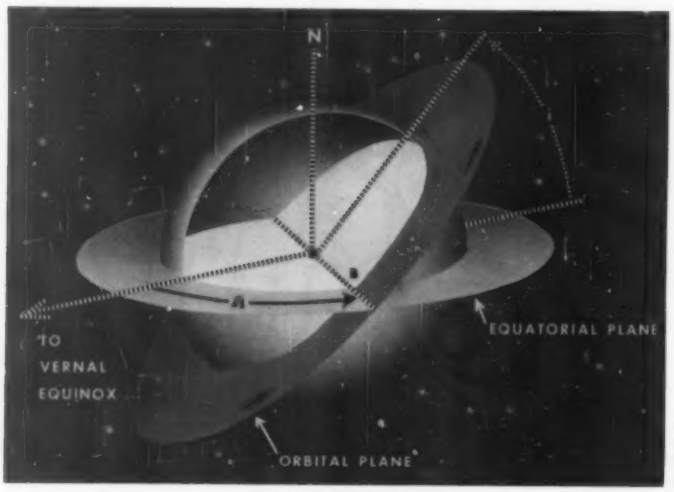

Figure 2

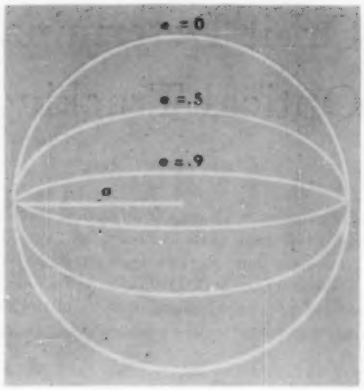

Fig. 3. Ellipses of constant size, a; and variable shape, e.

the perpendicular to the plane. Since this is a directed line in space, one could designate the direction of this line with respect to any coordinate system by designating two angles, for example, an elevation angle and a longitudinal angle. This demonstrates that two parameters or quantities are necessary to fix the orientation of the plane in space. An alternate method, much more generally used, is to consider the inclination of the orbit plane to some reference plane such as the plane of the Earth's equator. This angle is called the angle of inclination, and is one of the two quantities which must be designated.

For a given inclination, it is possible to see in Fig. 2 that there are an indefinite number of planes which all have the same inclination angle to the reference plane. However, it is also evident that their lines of intersection with the reference plane are different. Therefore, the second quantity necessary to fix the direction of the plane in space is logically chosen to be the direction of the line of intersection. This line of intersection is known as the line of nodes and its position is designated by an angle from some reference direction in the reference plane to the line of intersection. The angular distance from the reference direction is called the right ascension of the node, and the reference direction is the direction of the vernal equinox, which is that direction from the Earth towards the Sun on the first day of spring.

Now that we have determined the plane's orientation in space, we must designate the other parameters of the ellipse. To describe its size, we denote a quanity, a, which is the semimajor axis of the elliptical orbit or one-half of its maximum extent (Fig. 3). Now for a given semimajor axis, there is an entire family of ellipses of various shapes, ranging from nearly circular to extremely elongated shapes. The degree of elongation is given by the eccentricity of the elliptical orbit and is designated by small e. Referring to Fig. 3, for an eccentricity of zero, one would obtain a perfect circle

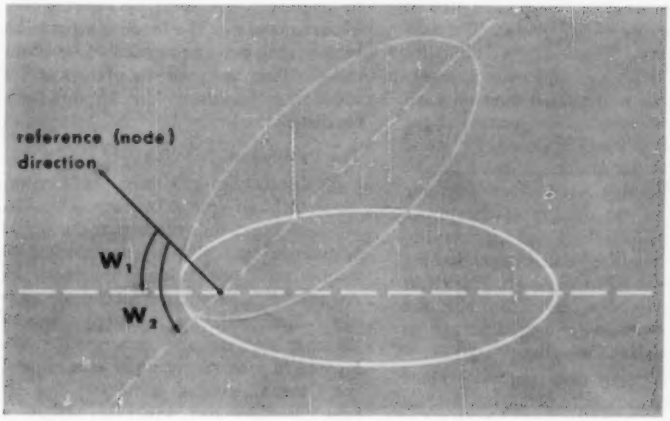

Figure 4

whose radius was the semimajor axis, a. As the eccentricity goes from zero to one, the ellipse becomes more elongated. When the eccentricity becomes one, we then have a parabolic orbit, in which case the motion about the object is not periodic or does not return.

In Fig. 4, we see that an ellipse of fixed size and shape can lie in an infinite number of ways in the prescribed plane, and that there must be an added quantity which fixes the direction of its long axis in that plane. In the case of orbits about the Earth, this direction is denoted by a quantity known as the argument of the perigee, w, which is simply the angular distance along the orbit from the node to the perigee, that point in the orbit where it is closest to the earth.

So far we have denoted five orbital quantities: two for the orientation of the plane in space, and three describing the size, shape and orientation of the ellipse itself. These five quantities suffice in the description of the geometry of the orbit. A sixth quantity is necessary, which is dynamical rather than geometrical in nature. At a particular instant, the orbiting body could be located at any place in the particular orbit. In order to remove this uncertainty, we must give the angular position of the body in the orbit at some referenced time; this time is called the epoch.

With these six orbital parameters, one defines a unique orbit which is different from any other possible orbit. The problem of orbit determination, therefore, resolves itself into the problem of determining these quantities for any body in question.

Since there are six orbital constants, it follows mathematically that only six observed quantities would be required for a unique orbit solution. These can be angles, distances, times, or any combination of these to total six. However, if we select some exotic combination of angles, times and ranges, we might well run into a practical problem in mathematics which would be almost impossible to solve or at best might require tremendous amounts of computation. It is therefore advisable to consider what combinations of observations provide a solution with a minimum amount of effort.

Easiest Determination of Orbit

At the Air Force Missile Test Center, we have found that the easiest way to determine an orbit is to have three completely specified geocentric position measurements each consisting of two angles measured from the center of the Earth, and a distance from the center of the Earth. The two angles were quite naturally chosen to be the latitude and longitude of the sub-satellite point (Fig. 5). In this case it is possible to separate the solution for the orbit into two distinct phases. This makes the overall problem less complex.

To begin with, we solve for the orbit plane. This is best done by taking the two end observations, that is, those which are the widest separated as to sub-satellite points. Since the intersection of the plane of an orbit around the Earth and the surface of the Earth itself must be a great circle on the surface of the Earth, all that is necessary is to pass a great circle through the two sub-satellite points and project it toward the equator until it crosses it. The angle at which this great circle crosses the equator can be shown to be equal to the angle of inclination. In a similar fashion one determines the longitude of the point where the great circle crosses the equator.

A knowledge of this longitude and the time at which the observations were made enables one to determine the orientation of the line of intersection of the orbit and equator planes, and, hence, the argument of the node. We, therefore, have then determined two of the orbital elements.

The basic equation which is that of an ellipse in polar coordinates is

$$r = \frac{a(1 - e^2)}{1 + e\cos(\theta - W)}$$

This equation relates the distance of the object from the center of the Earth,

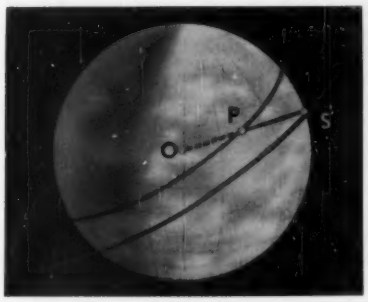

Figure 5

r; the semimajor axis, a; the angle of the body from the node in the orbit, θ; and the argument of the perigee, w. The angle θ can be easily obtained from the latitude and longitude of the sub-satellite point. Therefore, there are three unknown quantities in this equation, a, e and w. Any observed point for which r and θ are known gives one numerical relationship between the other three unknowns. It is therefore evident that three such observed points enable one to solve a set of simultaneous equations for the three unknowns. Hence, the necessity in this method for three observed points in space, each of which is designated by latitude and longitude and the distance from the center of the Earth.

Other Methods

There are other methods of determination which may be used. For example, perhaps the most simple method is the case in which position and velocity are known at some instant of time. This is a case where merely six quantities, namely three for the position coordinates and three for the velocity components suffice to determine the orbit without unusually difficult computations. However, accurate velocity measurements through the use of optical equipment are not readily obtainable, so that this method is not of as great value as the one previously described.

It is also possible to determine the orbit, given only two geocentric positions and the time difference between the two positions. This, however, leads to mathematical difficulties. Those who have dealt with problems of arcs along ellipses know that the determination of such arcs involves elliptical integrals, which are difficult to handle. Similarly, problems concerning the position of the body in the elliptical orbit as a function of time cause mathematical difficulties. Since it is unlikely that to obtain three geocentric positions (or more than three) will be more difficult than two geocentric positions, there is little to be gained by considering only two positions and using the more difficult solution.

Other methods are possible, but they all suffer from the necessity of complicated computational requirements. An example of note is where three widely

separated observations of azimuth and elevation angle from only one station are obtained. This is almost identical to the purely astronomical problem of determining the orbit of a planet or comet from three widely separated observations. It is, perhaps, the most difficult case to solve, but it merits attention due to the requirement for only one observational station. It should be added that due to the nature of the solution, the observation must satisfy certain conditions if a good solution is to be obtained. Merely obtaining any three sets of observations at random will usually not suffice.

Obtaining Observational Data

It seems fitting at this point to discuss the need for obtaining observational data on the same object on as many nights as possible. It was noted above that mathematical development of Newton's laws calls for an object retaining a stable orbit whose parameters remain constant indefinitely. This statement is exactly true only when two mass points attract each other gravitationally, with no other bodies present and no other forces operating. There are several reasons why these conditions are not obtained for a satellite or for a planet, so that changes in the orbital parameters do occur. Some of these changes can be computed with considerable accuracy, but there are others whose origin is uncertain. For example, if the Earth were a perfect sphere, it would then attract a satellite as if all of its mass were concentrated at its center. In other words, it would attract as a mass point. However, the well-known flattening of the Earth's poles, and the corresponding equatorial bulge provide an attraction near the Earth's surface which is slightly different from that of a hypothetically spherical Earth. This results in small steady changes or perturbations in two of the orbital elements. The argument of the node and the argument of perigee change steadily. As one gets farther and farther away from the Earth these effects diminish rapidly, but for satellites in the present era they are quite important. They do not, however, cause great difficulty since the Earth's size and mass distribution are fairly well known, and once an orbit is established these perturbations can be accurately computed for some distance into the future.

Recent satellites have shown that our knowledge of the density of the upper layers of the atmosphere and the resulting drag on the satellite passing through these layers is not at all well known. The effect of atmospheric drag is to diminish the period of revolution of a satellite and to decrease the size of its orbit.

Since this drag does not take place equally over the entire orbit, but mainly at perigee (the point closest to the Earth), it also changes the shape of the orbit or the orbital eccentricity. The tendency is to make the orbit more and more circular. The uncertainty, due to drag, in the period of revolution makes it impossible to project the future course of the satellite's period of revolution. For this reason, we cannot make predictions which are reasonably accurate for low satellites for more than a week into the future.

There also appear to be certain other effects whose causes are as yet uncertain. There is considerable evidence that at times of maximum solar activity, either corpuscular radiation or electromagnetic radiation from the sun causes changes to occur in the upper atmosphere which increase the drag effect of the atmosphere on the satellites. It is for these reasons, therefore, that it is not sufficient to obtain a determination of an orbit once and only once, and use it indefinitely for prediction purposes. One must obtain continuing observations in order to keep up with the changes of the orbit. Only in this way can one make valid position predictions for further observations or for discrimination among various objects.

It has been shown above that the easiest method of obtaining an orbit is by the use of three completely specified geocentric positions in which the range from the center of the Earth is included. Since it is not possible to obtain range directly through optical means, this must be obtained by triangulating the intersection of simultaneous lines of sight from two widely separated stations. In order to obtain this intersection locus with accuracy commensurate with the accuracy of the optical instrumentation, a proper choice of station separation or of baseline is necessary. If the baseline is too narrow (Fig. 6), the angle of intersection between the two rays will be quite oblique and there will be considerable uncertainty as to the exact radial position of the intersection and hence its space coordinates. To obtain accurate results, the angle at the intersection should be greater than 60°. That is, as seen from the satellite, the stations should be angularly separated by at least 60°. This requires that the baseline separation between the two stations should be about twice as large as the height of the satellite above the Earth's surface for optimum results.

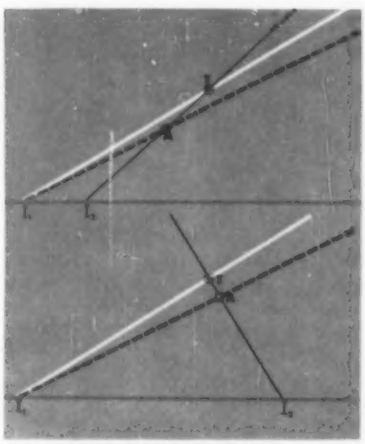

Figure 6

The Problem of Baseline

At the Air Force Missile Test Center, we were faced with a baseline difficulty. We had found that the best compromise between accuracy and possibility of obtaining rapid results lay in the use of the Askania Cinetheodolite *network* or *complex*.* Unfortunately, although seven of these existed on the range, all were located in a relatively small area around the Cape Canaveral launching area. It was therefore impossible to obtain a baseline of proper length for high positional accuracy. On extremely low satellite passes, those below 200 miles, some useful triangulated data were obtained but their accuracy was considerably less than that desired. Due to their ready visibility, the Sputnik rockets could easily be tracked at slant ranges up to 2000 miles. Obviously, a baseline of 10 to 20 miles in length, the maximum obtainable, was completely impractical here for any determination of slant range. It was therefore impossible to obtain accurate geocentric positions at these great ranges.

An excellent method of attacking this problem occurred to us. It is not difficult to visualize that the higher a satellite is above the Earth's surface, the wider the region above the Earth from which it can be seen (Fig. 7). A satellite which is 400 or 500 miles high and which has a period under two hours in revolution can therefore be seen above the horizon at a place on each of two successive revolutions. If the observing station is properly bracketed by these two, the possibility then arises of using only one observing station and utilizing the translation of the observing site due to the Earth's rotation to produce the necessary baseline. Since the Earth rotates in 24 hours, a point on its equator travels the 25,000 miles at a rate of a little more than 1000 miles per hour. Therefore, a satellite

* See, for instance: A. H. Schendel, "Optical tracking instrumentation," *Jour. SMPTE*, 67: 237–241, Apr. 1958.

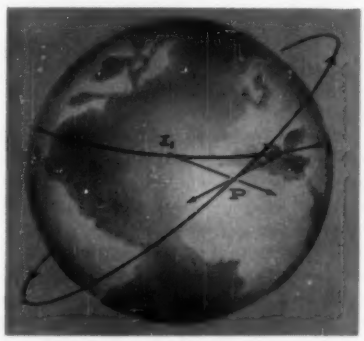

Figure 7

which has a period of, say, 90 minutes will successively cross the equator at points about 1500 miles west of the previous crossing. For satellites 500 miles or more from the Earth, observation at points separated by 1500 miles provides excellent geometry for determination of the intersection points on the orbit.

However, it is most important that in the selection of the data to be used for triangulation, angles to corresponding points of the orbit be properly chosen for pairing together. This is accomplished by observing the time when the satellite crossed the east-west line on each of the two revolutions. Differencing of the two times gives the period of revolution. By triangulating angular positions separated by this time difference, namely the period of revolution, it is certain that corresponding points of the orbit will be involved.

In the computational scheme the angular amount by which the Earth rotates during the time the satellite makes one revolution is computed. The angles from the second revolution are handled as if the longitude of the observing station were smaller than the true longitude by this same amount. The resulting situation is the same as if there were two tracking stations, both at the same latitude but widely separated in longitude. After final reduction, one obtains a triangulation of the full geocentric path of the satellite on its first revolution. This method was checked extensively early in 1958 on Sputnik II, and excellent results were obtained.

Experience With Sputnik III

On May 15, 1958, Sputnik III was launched. As was the case with the two earlier Sputniks, the carrier rocket was an object of large size, and hence easily visible to the unaided eye. However, in the case of this object, launching occurred at such a time that the orbit orientation carried it over the continental U.S. shortly after sunset that same evening. This produced an excellent situation for visibility from the surface of the Earth with sunlight reflecting brilliantly from the object, whereas the sky at the observing site was quite dark. Additionally, the particular portion of the orbit which lay over the U.S. was fairly high, so that the possibility of visibility during two successive revolutions presented itself. We were quite successful in obtaining data on the first revolution, since the carrier rocket passed at a very high elevation angle and was only about 600 miles distant.

The second pass occurred about 106 minutes later. The observing site was then located almost 1500 miles farther to the east relative to the orbit. The satellite, therefore, passed overhead at a point that much farther west from the observing station, and so, its elevation angle on this revolution was quite low and its slant range rather large. However, its great size and brilliance enabled us to pick it up at a slant range of some 1500 miles. It was then tracked almost all the way down to the horizon.

Table II. Orbital Points for Sputnik III. Supplement: Theodolite Station 1.20, Combination of A and B (1st and 2nd Pass); Test 1112–15 May 1958; Sputnik III—1958 Delta I, Epoch 2000.

Time (fast code)	Latitude (deg)	Longitude (deg)	Height (Statute mi)
476.00	25.0567	70.8990	618.99
477.00	25.0144	70.8883	619.03
478.00	24.9567	70.8486	620.46
479.00	24.8937	70.8189	621.25
480.00	24.8418	70.7967	621.93
481.00	24.7912	70.7760	622.18
482.00	24.7424	70.7481	622.60
483.00	24.6980	70.7268	622.18
484.00	24.6523	70.6983	622.67
485.00	24.5961	70.6773	623.33
486.00	24.5437	70.6512	624.76

Table III. Derived Orbital Elements—Sputnik III Rocket.

	May 15, 1958	May 17, 1958
Period	105.799 min	105.707 min
Semi-major axis	4604.1 mi	4601.7 mi
Eccentricity	0.1112	0.1103
Right ascension node	11.74°	6.72°
Argument perigee	58.44°	57.45°
Inclination	65.25°	65.25°

Determination of the period was made as described above, and triangulation of the points attempted. Table II shows the considerable degree of success in this triangulation. In it are tabulated the latitude and longitude of the sub-satellite point, and the height above the Earth's surface as a function of the number of seconds after 8:00 P.M. E.S.T. One can see the steady progress of the rocket southeast and the rapid increase in altitude as it headed towards its apogee which was then located in the Southern Hemisphere.

We chose only two of these points for use in the mathematical solution for the orbit. The reason that this was possible was that one of the orbit parameters was already known, namely, the period of revolution. We were therefore able to dispense with one of the points as unnecessary. The results obtained for the orbital elements are shown in Table III.

On May 17 we again succeeded in obtaining data on two successive passes, and the same type of reduction was made. Comparison of the two sets of data shows that the argument of the node has decreased. The argument of perigee has also changed, but by a smaller amount. Both changes were nearly those expected from theoretical considerations. The eccentricity of the orbit had also changed but only slightly. In addition, one can see the expected decrease in the satellite's period of revolution due principally to atmospheric drag.

Conclusions

It is felt that these examples of orbit determination from optical sightings demonstrate the relative ease and dependability of optical equipment for such purposes. Due to these past accomplishments, the Air Force Missile Test Center is in the process of installing theodolites of the same type on down-range stations so as to be able to achieve longer baselines for simultaneous triangulation in those cases for which two successive revolutions cannot be observed.

In addition to successes, there also appeared certain shortcomings which were obvious in our use of the theodolites. The 35mm photographic film required removing, transporting, development, reading and digitizing of the angles, all of which cause a considerable delay. In many cases, the importance of the results made it desirable to have them almost immediately. This requirement will increase in the future.

It therefore seems obvious that some better method of data readout is necessary. Probably the best solution is to digitize the output of the theodolite axes in a manner similar to the method used with most radars. The results can then be fed directly into a computer which can accomplish real-time position determination and, as a backlog of information is built up, real-time orbit determination. Of course, the accuracy of this information will be no better than the ability of the operators to point their tracking telescopes at the target, since the information obtained will merely be that of the pointing direction of the instrument rather than the direction to the target. What is needed over and beyond mere digitizing of the optical axis position angles is a real-time ability to determine a tracking error. There does not appear to be any reason why the image plane of a third collimated telescope could not be scanned by TV technique in order to determine displacement of the object from the center of the field. This displacement could also be obtained by a fine-grained mosaic of light-sensitive cells in the focal plane. Either method should produce (with suitable hardware) a digital tracking correction which, when added to the digital readout of the pointing direction of the instrument, would result in digital values of the position angles to the target. Only in this way will it be possible to construct a real-time optical orbit determination system.

Finally, a most important shortcoming of the theodolites is that of acquisition difficulty. The great size and brilliance of the Sputnik carrier rockets and the Atlas rocket made them easily visible to the unaided eye, and therefore easily acquired by the theodolite operators. The smaller American Explorers and the

Sputnik III nose cone present much more difficult targets. Much data has been lost due to their lesser brilliance to the unaided eye and the corresponding difficulty of seeing the object and lining it up in the tracking field of view. The field of view of most tracking telescopes is about three or four degrees in diameter. With the rapid changes in the orbital parameters described above making predictions uncertain, and with the tumbling motion that often occurs in satellites resulting in rapid changes in brilliance, we have found that it is almost impossible to acquire any of the smaller satellites in the field of view and achieve track. It is imperative, therefore, that a much wider field acquisition optical system be supplied. What is necessary is a field of the order of 20 or 30° with very little magnification and great light gathering power. In ordinary optical telescopes, these conditions cannot be met simultaneously. For example, exceedingly low magnifications which are necessary for obtaining very wide fields of view result in severe light losses so that the limiting magnitude will be severely curtailed.

There are several approaches that come to mind to remedy this situation. One of these is electronic image enhancement whereby the light losses will be made up electronically. Another possible method is the use of fiber optics to condense the real image produced by the objective down to a size that could be easily viewed by the visual eyepiece. Resolution would be badly limited by this method, but all we are looking for is detection capability, and as long as a faint moving point of light could be detected by this arrangement, it would be sufficient.

The solutions offered above would merely ease the difficulty of acquisition under ordinary dark or nearly dark conditions. Principal criticisms of optical tracking are twofold: first, it is limited by the weather; second, it is limited severely by the background radiation of the daytime sky. From the Earth's surface there is little one can do to get around the problem of obscuring clouds and haze other than site location in a favorable climatic area. However, it is felt that some progress may be possible along the lines of filters and image enhancement to enable optical tracking to occur at least during times of bright twilight and possibly during times of low Sun elevation on clear days. If this were possible, observation sites in dry locations with little cloud cover should be quite appropriate for obtaining large amounts of tracking data.

At the Advanced Research Projects Agency, it is felt that every attempt should be made to determine whether or not the use of electronic techniques and devices can facilitate the use of optical tracking instrumentation. Electronic instrumentation is exceedingly powerful but it should be recognized that optical instrumentation is far less expensive than the corresponding electronic instrumentation and, in the general sense, more reliable. So long as the Sun continues to shine and to illuminate targets at the rate of hundreds of watts per square meter, the electromagnetic radiations received at the Earth's surface from otherwise nonradiating satellites will be many orders of magnitude greater in optical frequencies than in radio frequencies. By proper utilization of techniques and methods at our disposal, we hope to make the maximum use of this optical radiation.

Discussion

S. Sternberg (*RCA Astro-Electronic Products Div.*): With the use of two successful passes as a baseline determining instrument, what is the sensitivity to drag during this time or its compensation?

Dr. Duke: There is little effect due to drag noticeable during one revolution of an Earth satellite unless its altitude is extremely low, in which case its remaining lifetime is only a matter of hours. While the ordinary effect of drag is important for uses of satellite position where the highest accuracy is required, such as geodetic work, this was not the case in our problem. To the accuracy to which we were working, the drag effect was of no significance.

There is one point I did not mention in my paper for the sake of simplicity which is important and had to be taken into account. The gravitational attraction of the earth's equatorial bulge causes the satellite orbit to precess. Since the magnitude of this may amount to a considerable part of a degree during one revolution of a satellite, it cannot be ignored.

Image Sensing as Applied to Meteorological Satellites

By DAVID S. JOHNSON

Earth satellites provide meteorology with an observing platform commensurate with the global nature of weather. One of the most promising satellite observations is of cloud distribution and type. Several image-sensing systems are being considered. Cloud images, both day and night with a resolution of about 0.5 mile, are ultimately desired. Problems in sensing instrumentation, communications, processing and data presentation must be solved before an operational system becomes a reality.

EVEN WITH THE RAPID advances in meteorological observations during recent years, only a small percentage of the Earth's atmosphere is adequately probed by conventional meteorological observations. Thus, large storms can reside undetected for days in many desert, polar and oceanic areas of the world. Even in areas having dense meteorological networks small storms are probably often not detected.

Conditions in the atmosphere in one region of the Earth may influence the subsequent weather conditions in a distant part of the Earth's atmosphere. These atmospheric interactions, global in nature, require an observing system which is global in scope. The artificial Earth satellite offers the meteorologist an observing platform which will permit every point on the Earth's surface and in the Earth's atmosphere to be observed at frequent intervals.

The Earth's weather is determined primarily by conditions existing in the lowest 40 miles of the atmosphere, far below usual satellite altitudes. Therefore, meteorological satellite observations so far suggested depend on some type of radiation measurement such as solar radiation reflected, and infrared radiation emitted, by the Earth and atmosphere, or electromagnetic radiation emitted from a satellite and reflected back by the Earth and atmosphere. Many of these measurements involve image sensing. Indeed, the application of image sensing to cloud and precipitation detection appears to offer the best possibility for the first operational use of meteorological satellite observations.[1] Thus, considerable emphasis is being placed on the development of techniques for obtaining cloud images from satellites at night

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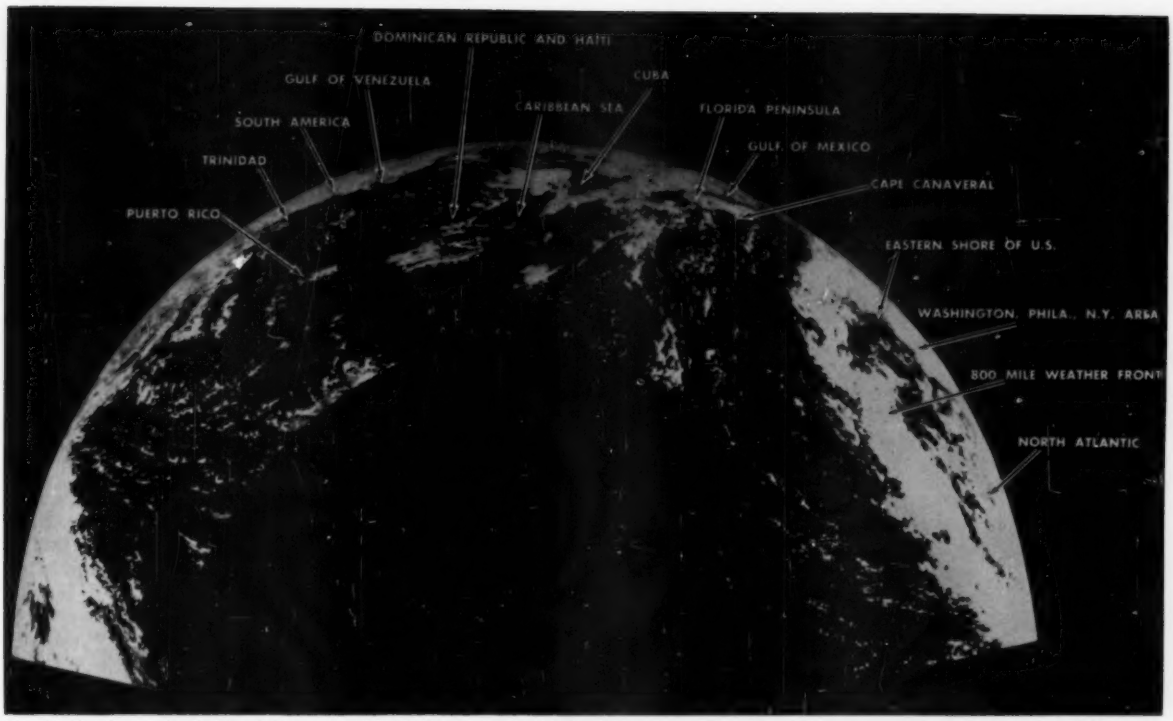

Fig. 1. Cloud mosaic obtained from a rocket flight southeast of Florida on Aug. 24, 1959. The camera was at an altitude of 300 to 400 nautical miles when these pictures were taken. (Mosaic prepared by Missiles and Space Div., General Electric Co., Philadelphia.)

as well as in daylight and on the use of radar to obtain images indicating areas of rain and snow.[2,3]

Image-Sensing Requirements

To obtain global coverage at frequent intervals, Earth-oriented satellites in quasi-polar orbits are required, equipped with sensors which can provide useful information both night and day. The image sensors must view an area determined in one dimension by the distance on the Earth's surface at the equator between adjacent orbits. For example, for a satellite at an altitude of 800 nautical miles, this distance is about 1730 nautical miles and defines an included angle of view of about 87°.

It is difficult to define the resolution required in cloud imaging for meteorological applications. This is due both to the problems of "seeing" for target identification and the variation in information content required for different meteorological applications.

Target or cloud recognition is a function of the relative contrast between the target and its background as well as the resolution and available illumination. Clouds must be observed against a background of the Earth's surface. The reflectance or albedo in the visible part of the spectrum for the Earth's surface varies from as low as 3% for water with solar elevation angle greater than about 30° to over 80% for a fresh snow surface. Cloud albedo varies from less than 10% to more than 80% depending on cloud type and thickness. Therefore, in many cases, the brightness contrast may be quite small and even zero in some cases. The effect of atmospheric scattering on brightness contrast is discussed later. As the brightness contrast decreases, higher resolution is required for the eye to just identify a specific target.

Resolution. Consider next the resolutions dictated by meteorological requirements, assuming that all clouds can be distinguished from their backgrounds. At least three types of information are desired from cloud images obtained by satellites: first, the determination of the percentage of a given area covered by cloud; second, overall cloud patterns or orientations such as vortices and lines of clouds or cloud "streets"; and third, the determination of cloud type by its shape, size, texture and distribution. Each of these, to some degree, places different requirements on resolution. A reasonable measure of cloud amount, averaged over an area of at least several hundred square miles, can probably be obtained with a resolution as poor as two or three miles. Cloud patterns or orientations can be determined with reasonable certainty, in many cases, with a resolution of about one to two miles. Better resolution may be required where cloud elements are viewed at an oblique angle. Considerably better resolution will often be required to determine cloud type.

There is, at present, considerable conjecture in arriving at values of resolution required for meteorology. We are used to observing clouds by viewing them from below. It is only very recently that research meteorologists have had a downward view of clouds over large areas by means of rocket photography and we have yet to obtain useful cloud images from satellites. Therefore, the meteorologist must gain new experience before arriving at any precise determination of the resolutions required in cloud imaging from satellites.

Cloud photographs obtained from high-altitude rockets and missiles, such as the one shown in Fig. 1, are now being studied to define more precisely the resolutions required. Preliminary results indicate that with a reasonably high contrast ratio, a resolution of about one mile is adequate for many meteorological applications. With a resolution of only two miles, some details are lost, although much valuable meteorological information is usually retained. Resolutions better than one mile provide additional cloud information although the maximum desirable resolution has not been precisely determined. At present, it is believed that ultimately a resolution of at least one-half mile, not considering brightness contrast, is desirable.

The geometry of the object field enters into the determination of the system resolution. The satellite is viewing the Earth's curved surface. As mentioned earlier, an arc on the Earth's surface about 1730 nautical miles long normal to the satellite's orbital velocity vector must

be included in the field of view from a polar orbiting satellite 800 nautical miles above the equator to obtain full coverage of the globe. To obtain the desired resolution of one-half mile at the edge of the object field, 865 miles from the satellite sub-point, an angular resolution of about 0.012° would be required. This angular resolution would give a linear resolution on the Earth's surface at the satellite subpoint of 0.16 miles.

Sensitivity. The sensitivity and dynamic range of image sensors is of considerable importance. The meteorological requirement in this regard is simply stated: "We want to 'see' all the clouds all of the time." However, it is quite difficult to convert this to meaningful engineering requirements. Several factors must be considered. For example, the type of image-sensing system is important, such as a system sensitive to reflected solar radiation as compared to one responding to self-radiation in the infrared. The range in contrast between target and background is important as is the albedo and radiational properties of both the target and background. Scattering and attenuation in the atmosphere between the object field and the satellite must also be considered.

Utilizing radiation in the visible part of the spectrum, the meteorologist ultimately would desire a sensor which could detect clouds when illuminated by sunlight, moonlight, or even starlight. This represents a fantastic range in incident illumination.

The radiation received by a unit area at the Earth's surface decreases as the angle of incidence departs from normal due to the cosine law and the incident radiation having had a longer path through the atmosphere. For example, the direct solar radition received on a unit horizontal area at the Earth's surface with a solar elevation angle of 18° is about two-tenths that which would be received by the same area with the sun directly overhead.

While atmospheric scattering reduces the amount of energy received by the satellite from the target, it also reduces the relative contrast between the target and its background. This is a particularly serious problem for targets located on the Earth's surface where the light reflected by both the target and the background are subjected to the same amount of scattering. In cloud identification the problem is not nearly as severe. The particulate scattering decreases quite rapidly with height above the earth's surface. Most clouds have tops which are at least 5,000 ft above the Earth's surface. Also, in many cases, the cloud tops are associated with a temperature inversion which tends to limit the majority of the particulate matter to the atmosphere below the inversion. Therefore, in general, the radiation reflected by the cloud tops will be subjected to considerably less scattering than that reflected by the Earth's surface. The effect of molecular, or Rayleigh scattering, can be minimized by filtering out the blue part of the spectrum. As a result, in most cases the relative contrast between the clouds and their backgrounds should not be seriously reduced by scattering. However, particulate scattering will increase the effective albedo of the background. In the case of sensors depending upon solar radiation, the relative contrast can be increased by limiting the spectral response of the sensors. Some experimental evidence[4] suggests that a 0.2-μ interval centered at a wavelength of about 0.65μ would provide the optimum relative contrast, considering the wide variety of backgrounds, including oceans and vegetative matter, which will occur. Of course, limiting the spectral interval will require greater system sensitivity.

Infrared. The previous discussion has been concerned with image sensors responding to radiation in the visible portion of the spectrum. Somewhat similar problems must be considered in the case of infrared image sensors. In this case, imaging depends upon differentiating the radiation emitted by clouds from that emitted by the background. The relative contrast is diminished by the radiation also emitted from the atmosphere.

The amount of energy emitted by an object is a function of its emissivity and temperature. As an approximation, many clouds and the Earth's surface can be considered blackbodies (emissivity of one). The difference between cloud top and Earth temperatures will largely control the contrast between the desired image and its background. In polar areas, low clouds are often warmer than the surface beneath while in tropical and temperate zones, clouds are generally colder than the Earth's surface. On some occasions, there may be no difference between the cloud top temperature and the Earth's surface temperature.

The atmosphere, particularly water vapor, carbon dioxide and ozone, also emits radiation in the 5- to 30-μ region. This radiation reduces the relative contrast between the cloud top and the underlying Earth's surface.

The problems of infrared image sensing are covered in more detail in a paper by Hanel and Stroud.[5]

Cloud Image-Sensing Techniques

Object Scanning. The simplest form of image sensing utilizes mechanical or object scanning induced by the motion of a spinning satellite. Such a system was used in the Vanguard II cloud cover experiment devised by Stroud and his associates while at the U.S. Army Signal Research and Development Laboratories.[6,7]

In this first attempt at image sensing from an Earth satellite an optics-sensor system was utilized having an included angle of view of one degree and sensitive to radiation between about 0.6- and 0.8-μ wavelength. Two sensors were utilized pointing in opposite directions with their optical axes 45° from the satellite spin axis. As the spinning satellite moved in its orbit one of the two sensors would scan the Earth's surface. With the proper spin rate and altitude the individual scan strips would be contiguous. The output of the sensors was amplified and the information stored on a magnetic tape recorder for relay to the Earth when the satellite was interrogated by a ground station.

For optimum results this system requires a nearly circular orbit, stable spin axis, and a spin rate determined by the angular resolution of the optics and the altitude of the satellite. In the case of the Vanguard II experiment the orbit was quite elliptical, the spin axis had large perturbations and the spin rate was considerably less than the design value. Therefore, even though the instruments worked perfectly, it has so far not been possible to reconstruct the data in the form of cloud photographs.

The basic simplicity of this system has considerable merit. It deserves further consideration when satellite motions can be precisely controlled. Alternatively, the system could be used by providing mechanical scanning on an Earth-oriented satellite where the satellite axis is normal to the Earth's surface and there is no rotation of the satellite about this axis. However, considerably better resolution is desired than that used in the Vanguard II experiment. With the development of instruments with high sensitivity in the infrared region of the spectrum, this type of system offers promise for cloud imaging at night as considered by Hanel and Stroud.[5]

While a mechanical-scanning system simplifies the instrumentation in the satellite, it adds to the complexity on the ground. The scan information must be properly reconstructed in picture form and located with respect to the Earth's surface. The data, to be of operational value in meteorology, must be rapidly converted to usable form after receipt on the ground. Particularly in the case of a spinning satellite, all of the orbital parameters would have to be known precisely ahead of time in order to meet this time requirement.

Electronic Image Scanning. Some of the problems of the mechanical scanning system can be overcome by the use of electronic image scanning. An instantaneous view of an area on the Earth's

Fig. 2. Simulation of type of picture which might be obtained with image scanning, based on rocket photos taken at about 80 nautical miles above White Sands, N.M. (Original photo by U. S. Naval Research Labs., simulation by Astro-Electronic Products Div., Radio Corp. of America.)

surface can be imaged on the photosensitive surface of a photoconverter tube such as a vidicon or image orthicon and an electron gun used to scan this image plane.

While knowledge of the motions of the optic axis of the imaging system is still required to locate the resulting cloud picture with respect to the Earth's surface, this need be done only once for each picture. In addition, information in the pictures themselves will assist in this location process. This image-scanning system has the further advantage that the pictures can be reconstituted rapidly after receiving the signals at the ground.

Figure 2 is a simulation of the type of picture which might be obtained with an image-scanning system. The original cloud mosaic was prepared from a series of photographs taken at an altitude of about 80 nautical miles on a rocket launched from White Sands, N.M. The mosaic was scanned electronically, using a 21-db signal-to-noise ratio, and the resulting image displayed on a television monitor and photographed.

The spacing between adjacent scan lines in the center foreground is equivalent to about one mile on the ground. The distance between line pairs increases as one approaches the horizon, probably averaging more than ten miles in the upper part of the picture. Even with this resolution, many of the major cloud features are retained.

While Fig. 2 approximates the resolution which may be obtained from early meteorological satellites, improvements in sensors, data storage and communications should eventually permit the optimum coverage and resolution desired by meteorologists.

With present electronic scanning systems we are limited to daylight operation. However, recent laboratory results hold considerable promise for the application of high sensitivity, image-orthicon or image-converter tubes for nighttime use, at least with moonlight. The possibility of high-resolution nighttime cloud observations warrants their serious consideration for meteorological satellites.

Electrostatic Imaging and Recording. A serious problem in cloud imaging from satellites is the storage of the video data for subsequent playback when the satellite is within contact of a readout station. Magnetic-tape recorders are presently used on many satellites; however, it is doubtful that this storage medium is practical for a system which would meet the ultimate meteorological requirement of worldwide coverage and a resolution of about $\frac{1}{4}$ mile. Current laboratory work utilizing electrostatic tape as a storage medium indicates a promising solution to this problem. Also the electrostatic tape can serve as the photosensitive surface.

It appears that this electrostatic system, combined with a suitable optical system, can come close to meeting the ultimate in meteorological requirements, at least for daytime operation. The work of one laboratory in this area is reported by Hutter, Inslee and Moore.[8]

Data Storage, Transmission and Processing

While the primary subject of this paper is image sensing, the problems of storage, transmission and processing of the sensed information must be recognized as they are of comparable magnitude to the problems involved in the image sensing itself.

For example, a polar orbiting satellite at an altitude of 800 nautical miles, viewing a strip on the Earth's surface 1750 miles wide, with an angular resolution of 0.012° both day and night, would result in approximately 10^9 bits of data being collected during one orbit. Since it is not practical to read out these data more frequently than once per orbit, all these data must be stored for subsequent playback. A storage medium of high packing density is required for compatibility with the size and weight limitations of satellites which will be available in the near future. A maximum of about 10 min would probably be available for the readout of these stored data, requiring a bandwidth of about 1.7 mc.

After signals are received on the ground they must be processed rapidly and the cloud information located with respect to an Earth coordinate system so that the meteorologists can utilize the data. This is difficult to accomplish at present with the use of spin stabilized satellites generally in elliptical orbits. The use of stabilized Earth-oriented satellites in circular orbits would simplify the picture location problem. It should even be possible to develop a nearly automatic system for processing and locating the cloud image data.

Unfortunately, the readout stations usually are not located where it is desired to use the meteorological satellite data. Therefore, it is necessary to transmit this information to various points on the Earth where it is required. For example, the Weather Bureau's National Meteorological Center is located in Washington, D.C. For full operational utilization of the cloud image data it will be necessary to transmit the information from the readout stations to this center.

Initially, it probably will be necessary to have meteorological groups at each of the readout stations perform a preliminary analysis of the cloud pictures obtained. The results of these analyses could then be transmitted to various meteorological centers by either facsimile or teletype. Ultimately, communication satellites may provide a means of transmitting the picture information directly to meteorological centers for analysis.

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Image Sensors and Space Environment

By MILTON RITTER and M. H. MESNER

A brief description is given of the satellite environment. The constraints and deleterious effects of the environment on image sensors and sensing systems are evaluated. Environment-induced engineering modifications of the vidicon are discussed.

THE USE OF image sensors for reconnaissance and weather mapping has been accelerated with the advent of the satellite-space age. This is not an unmixed blessing for the system designer, however. The space environment encountered by satellites or space vehicles introduces constraints and hazards on the functioning of image-sensing systems for which he has little or no experience.

Loss of Atmospheric Cooling

As a starting point, consider the atmospheric pressures at satellite altitudes. Figure 1 indicates that at 200 statute miles, static pressures are in the order of 2.6×10^{-10} psi or 1.3×10^{-8} mm mercury. For an orbiting satellite or a vehicle velocity of 26,000 ft/sec at this altitude, anticipated dynamic pressures are in the order of 10^{-8} psi or 5×10^{-6} mm mercury.

The first problem area resulting from the reduced pressures at satellite altitudes results when inquiry is made into the heat transport capabilities of this atmosphere. Figure 2 shows experimental data from a test we made on surface radiative properties. In determining whether we had a true radiation equilibrium, investigation was made of the pressure dependence of the equilibrium temperature of the sample under test. The sample was in a vacuum chamber, with a liquid nitrogen temperature surround. A solar flux entered through an aperture. In thermal equilibrium the only term dependent upon the pressure is the atmospheric transport, $k(p)\frac{\partial T}{\partial n}(p)$. Since no further changes in equilibrium temperature occur below pressures of 10^{-4} mm mercury, it must be concluded that the atmospheric conductance had become negligible at this pressure. At satellite altitudes, however, the molecular temperature of the atmosphere is in the order of 2500 K. The conductance is proportional to the square root of the absolute temperature. The dotted line on the curve in Fig. 2 takes this factor into account.

As a consequence of the reduced pressures, the atmosphere cannot conduct or convect heat between the thermal sources and sinks on the satellite. Thermal communication is limited strictly to radiative coupling and solid conduction. Bonding terminals must be welded or conductively cemented to preclude vacuum gaps and consequent large thermal gradients.

Defined operating temperatures for heat-dissipating components have no meaning since the "ambient air" can no longer perform its cooling function.

Consider an electron tube. Increasing the bulb temperature very drastically decreases its survival capability. With the loss of normal convective and conductive cooling of the air the bulb tem-

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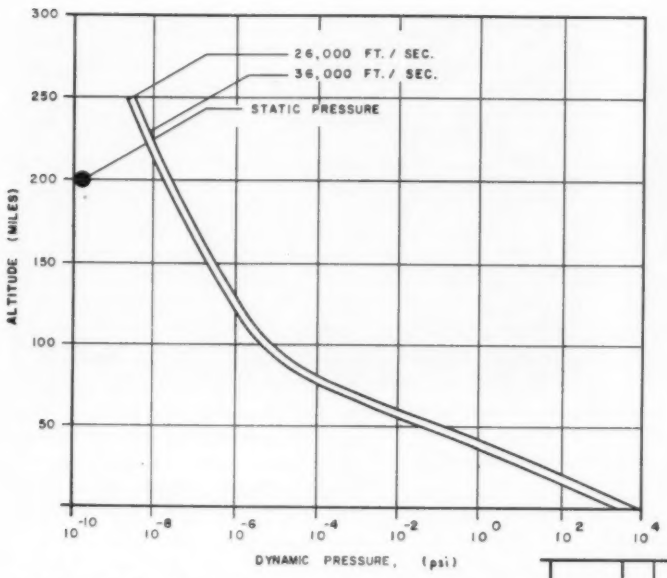


Fig. 1. Altitude dependence of pressure. (C. F. Hansen, "Some characteristics of the upper atmosphere pertaining to hypervelocity flight," *Jet Propulsion, Jour. Am. Rocket Soc., 27:* 1151–1156, June 1957.)

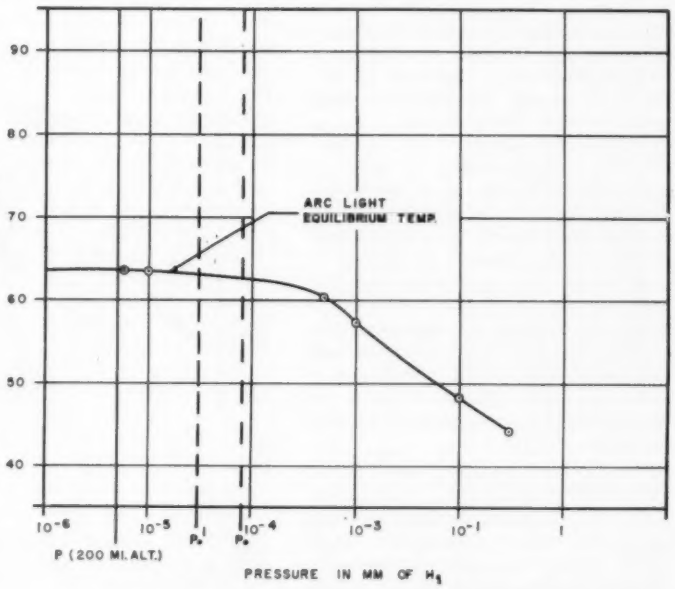


Fig. 2. α/ϵ experiment vacuum dependence; P_0 threshold of conductance at 80 C; P_0' effective threshold of conductance at 2500 K. α = solar absorptivity; ϵ = thermal emissivity. (Gary D. Gordon, RCA, August 20, 1959.)

perature must rise appreciably and the tube life is jeopardized. Present designs call for performing the required cooling function by thermal shields which make good contact with both the bulb and structural members of the satellite.

Corona Discharge (Arc-over)

The breakdown potential (see Fig. 3) for a gas of atmospheric composition drops 300 v for a product of pressure p, and gap distance d, equal to $\sim$0.6, where p is in mm Hg and d in cm. At satellite altitudes this product, pd, is so small as to pose no problem. In the ascent, however, conditions may be realized wherein arc-over could occur. Considerations, therefore, relative to the ascent phase, must include the possibilities of reduced voltages, encapsulation, or initiation of operation after orbit has been obtained. This phenomenon of arc-over can be experienced the hard way, painfully. It never fails but that someone puts a high-voltage equipment into operation before pulling a hard vacuum rather than vice versa.

Explosive Decompression

Explosive decompression may occur in component containers in which an arbitrary pressure is maintained, when the external pressure drops sufficiently. In addition, puncture of the container by micrometeorites will create an outward rush of air with possible deleterious effects on component supports.

In some cases it may be advisable to employ dessication in lieu of hermetic seals for ground-handling humidity problems.

Boiling and Leakage Through Seals

Boiling points of liquids at the pressures associated with satellite altitudes will be greatly lowered. At temperatures to be encountered, many fluids will boil and seep out of their containers. This effect may be enhanced by differential thermal expansion with consequent loosening of seals and gaskets. The condition of zero gravity at low pressures adds the complication that escaping fluids will continue to move in the direction of their escape. Loss of heat transfer medium (by micrometeorite puncturing of pres-

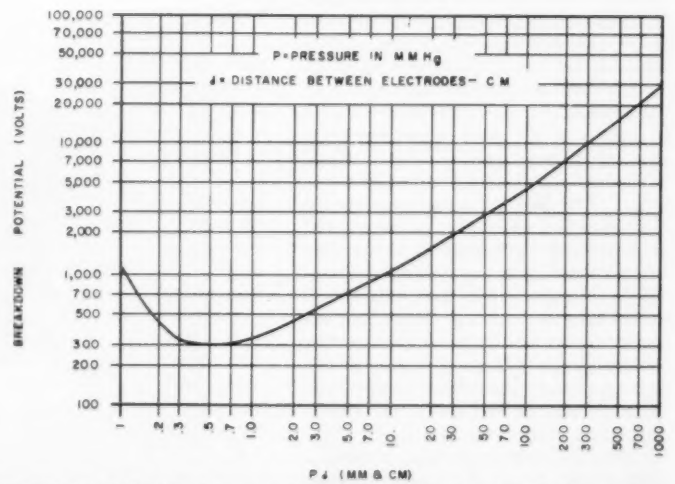


Fig. 3. Characteristics of the breakdown potential. (J. M. Meek and J. D. Craggs, *Electrical Breakdown of Gases*, Oxford University Press, 1953.)

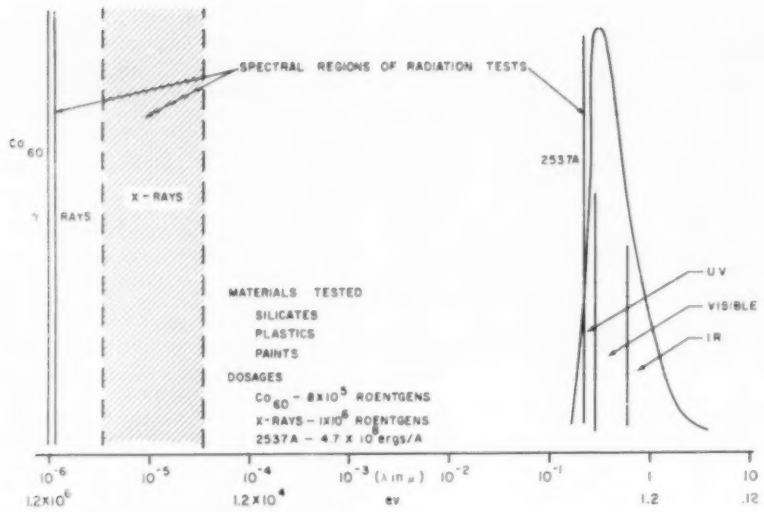


Fig. 4. The solar spectrum above the Earth's atmosphere. (Gast, *AFCRC Handbook of Geophysics for Air Force Designers*, 1959, Chap. 16.)

surized containers) may cause components to reach temperatures which would result in malfunctioning.

A typical example, which has been studied at our installation, arises in connection with the use of antifriction bearings for rotating members. Under normal atmospheric conditions it is possible to use conventional ball bearings lubricated with low-temperature and low-volatility oils. At reduced pressures, however, this presents an insurmountable problem of outgassing, not only through the loss of lubricant, but much more in the poisoning of emissive elements and the coating of optics present in the same envelope.

Solar Radiation

Figure 4 indicates the solar spectrum above the Earth's atmosphere which fairly closely approximates that of a 6000 K blackbody. Of greatest interest in terms of radiation damage to materials is the ultraviolet and x-ray region. The flux in this region constitutes approximately 9% of the total solar emission. Superposed on the solar photoemission spectrum is the Van Allen Radiation Belt of electron and/or proton fluxes which is now believed to be solar in origin. The general characteristics of the radiation belt are shown in Fig. 5. The numbers refer to counts of high-energy particles per sq cm per steradian per sec. Latest satellite probes are revising upwards both the intensity values and the extent of the belts. The maximum flux occurs in the soft x-ray region of 50-kev electrons; the higher-energy particles lie beyond 75 mev in the energy spectrum. With the aid of Signal Corps facilities we conducted radiation damage tests on materials which we were considering as possible surface coatings for satellite thermal control and for thermal protection of the silicon solar cells used for power generation on satellites.

Figure 4 shows the spectral regions, the dosages applied, and the types of materials investigated. It is of interest to note that a full spectrum analysis must be made since it was found, in several cases, that materials showed effects in only one of the three regions, and these were not in the same region for different materials. The dosages for the ultraviolet and x-ray tests are effectively a year's input of the radiation belt maximum intensity. A typical result which has interest for image sensors is shown in Fig. 6. On the right is a control glass slide — not irradiated. On the left is a plastic-coated slide irradiated by an 800,000-roentgen dosage of a Co-60 source. The radiations are gamma rays

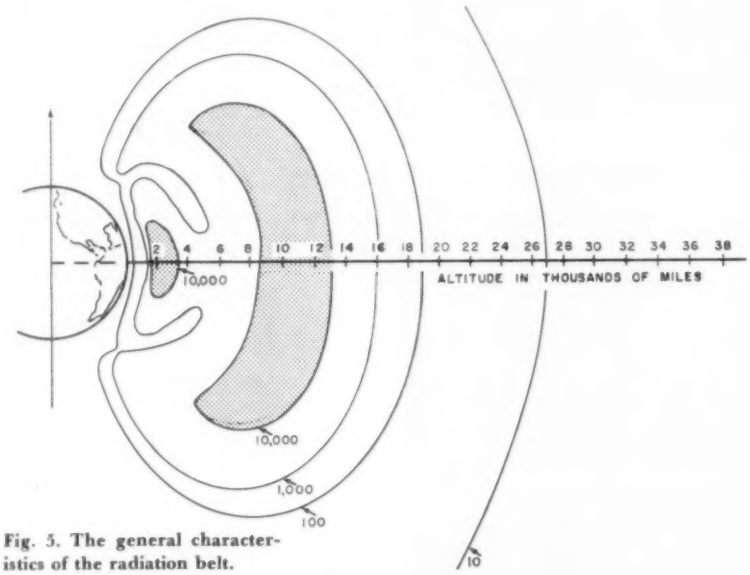
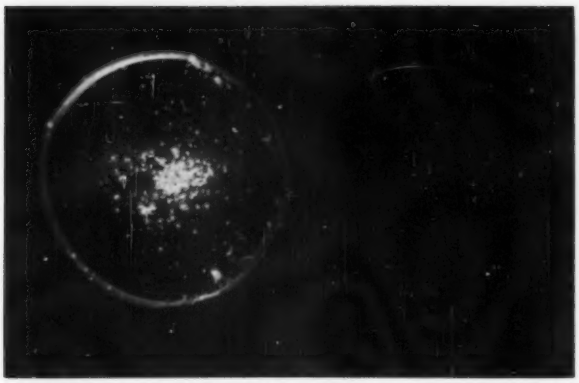
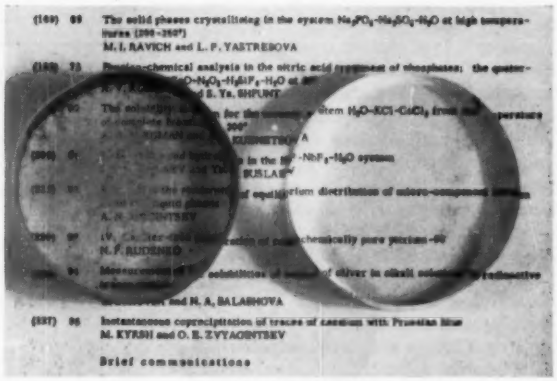


Fig. 5. The general characteristics of the radiation belt.

Fig. 6. Results of a Co-60 radiation test.





Figs. 7A and B. Simulated micrometeorite bombardment of a glass and a Lucite disc with steel particles. (From the work of T. C. Poulter, Stanford Research Institute.)

of 1.1 and 1.3 mev. It can be seen that both the glass and the plastic have browned under the radiation and, as would be expected from the penetrating gamma rays, the browning is a volume effect (the thicker the material the greater the browning).

Unfortunately, this was common slide glass; lens glass was not tested. If a particular glass does exhibit browning per unit thickness, then the multiple-lens system of camera optics, using such glass, should suffer very large total losses in transmission.

Solid Particles

Meteors having masses greater than 1 μgram can penetrate skin thicknesses of 0.040-in. aluminum on impact. Smaller micrometeorites will sandblast a surface, and hence, will create changes in surface optical and radiative properties which will change equilibrium temperature distributions on the satellite.

Evidence to date on meteorite distribution at satellite altitudes appears to fluctuate widely. Microphone impact measurements on the 1958 α, γ, and on the 1959 Paddle Wheel satellite show a mean flux rate of 10^{-3} to 10^{-2} particles/sq m sec with diameters greater than 3μ. Russian data, on the other hand, seem to indicate counts of 90 to 100 particles/sq m sec with diameters of at least 10μ. This is 10,000 to 100,000 times greater than the American measurements indicate. Recently, however, there is indication that the Russian data have been revised downward to a much closer agreement with the American data. A second type of measurement of micrometeorite activity is the grid-wire experiments, wherein a grid wire is ruptured when an impact from a micrometeorite larger than a preassigned diameter is received. For Explorer I (1958) not more than one (and perhaps none) of the wire gauges were broken during the lifetime of the telemetering system. For Explorer III no grid wires were broken between the launch date 3/26/58 and 5/6/58. Between 5/6/58 and 5/7/58 two grids were fractured. It is perhaps advisable at this point to quote from the Jet Propulsion Laboratory's *External Publication No. 538:*

"This occurrence was followed by an interesting series of happenings. On May 8 and 9 erratic behavior was observed in one of the telemetering channels on the low-power transmitter. After 0415 G.M.T. on May 9 no signal at all was observed from this transmitter. During May 10 and 11 the Minitrack receiving stations indicated intermittent operation of the high-power transmitter, and after May 11 no further signals were received for several days. After a period of a few days both transmitters returned to operation. However, the low-power transmitter carried no telemetry signal, and the operation of the interrogated beacon was intermittent.

"The coincidental failure of these two transmitters is curious. The two units operated quite independently with separate circuitry and separate power supplies. It was expected that they might have similar lifetimes, but failure of both within one or two days of each other simply from coincidental power failures is not very likely.

"One other item of information must now be introduced. All of the micrometeorite data before this time were taken in a period of normal background activity. No meteor showers were encountered. However, the shower Eta Aquarides, which has been associated with Halley's Comet, occurs during the early part of May, reaching its most intense activity on about May 5. It is therefore very suggestive that the fracture of two wire gauges and the very nearly coincident failure of two independent radio systems followed within a few days of the predicted time of this meteor shower. It is reasonable to speculate that some sort of internal damage was caused by impact of meteorites."

More information came from an IRBM sent up in May, 1959. Here there were 8 grid wires positioned on each side of the payload. The telemetry signals were functioning quite normally when suddenly within a few seconds all 8 grids on one side were fractured. The fluctuations in reported micrometeorite activity thus appears to be the actual state of affairs rather than measurement errors.

Figures 7A and 7B indicate the results of work by Stanford Research Institute in bombarding a Lucite and a glass disc supplied by RCA with steel particles, ranging in size from less than 3 μ to 25 μ, with velocities in the order of 18,000 ft/sec. The surface of the glass disc is badly shattered with a resultant 25% decrease in transmission, whereas the Lucite has absorbed the particles and re-formed around them with negligible transmission loss.

It is not meant to imply that bombardment shown here constitutes the mass and velocity distributions of micrometeorites in space, but rather that the qualitative damage effects are dependent on the hardness of the object undergoing the bombardment. The extension of these results to camera optics is obvious but the solution is not. Substitution of plastic lenses would probably create more problems from radiation and outgassing than would be solved in terms of micrometeorite damage.

Dissociated Gases

At satellite altitude, the constituents of the atmosphere are dissociated. Atomic oxygen will react with heavy metals such as iron, copper and silver, and with many organic materials. Consideration should therefore be given to the avoidance of materials that do not form adherent oxide layers. In cases such as electrical contacts, where oxide formation is intolerable, the use of noble metal coating or atmospheric shielding is indicated.

Atomic (nascent) nitrogen poses a problem only where exposed metals are at high temperatures.

At satellite altitudes, the concentra-

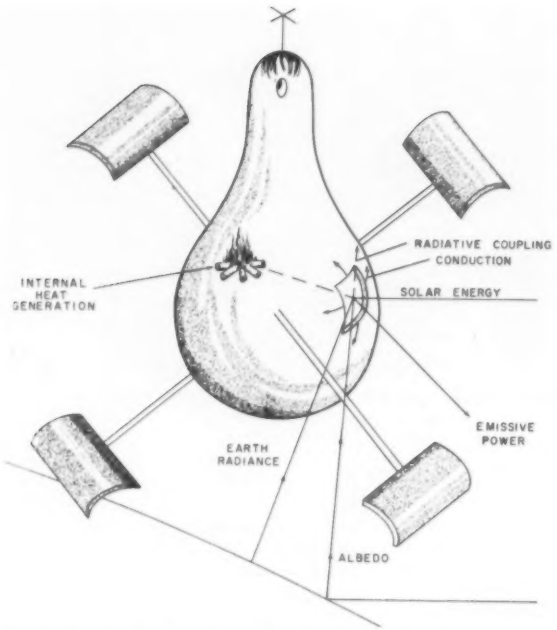


Fig. 8. Typical satellite in orbit showing radiant-heat inputs and internal heat generation.

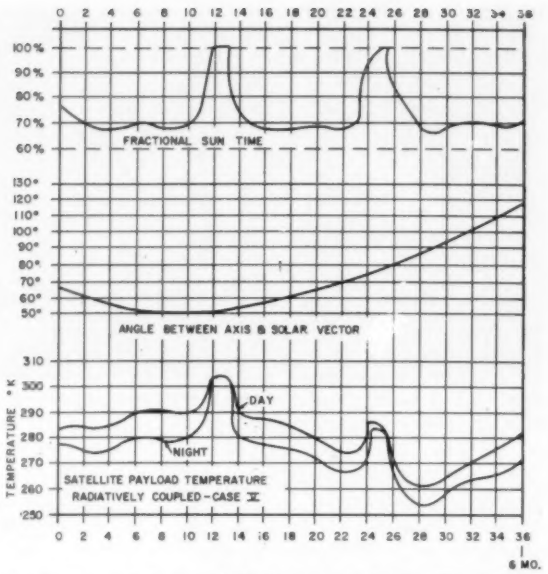


Fig. 9. Thermal characteristics for a particular satellite nearing completion.

tion of ozone is negligibly low and does not constitute a hazard.

Induced Environments

The major induced environments which result from the action of the space environment on the satellite are the following:

(1) Acceleration and shock,
(2) Vibration,
(3) Zero gravity, and
(4) Thermal.

The first two categories are not isolated to the satellite environment. The equipment designer is likely to have had experience with problems resulting from acceleration and vibration. For the sake of brevity these will not be included in this discussion.

Zero gravity presents new types of problems. A nonspinning satellite, in a circular orbit, must present a force-free environment to its mass elements and this presents problems to the designer, a few of which are:

(a) Air bubbles will not rise in batteries and thus will contaminate the plates.

(b) Direction-sensitive devices, pumping devices dependent on hydraulic heads, equipments that will operate only in a given orientation, and any device working on fluid level will not operate properly.

(c) Clearances in spring-mounted equipment will change.

Thermal Problems

Figure 8 shows a typical satellite in orbit. The radiant-heat inputs and internal heat generation are indicated. To obtain the thermal distribution a fairly complex problem in heat conduction with radiation boundary conditions, confounded by difficult geometrical considerations, must be solved. Without going into the details of the calculation, the results for a particular satellite which is nearing completion are shown in Fig. 9.

This shows the predicted dynamic thermal distribution through the first half-year of the life of the satellite. The pertinent thermal features, which apply in general to all satellites whose thermal controls are purely passive, that is, have fixed-surface radiative properties and fixed internal conduction and radiative coupling, are:

(1) Any arbitrary mean temperature can be obtained by the appropriate choice of surface-radiative properties relative to the mean radiation inputs to be encountered.

(2) The orbital day-to-night variations in temperature of the interior package can be made negligible by increasing the effective thermal mass (the product of the thermal masses and the thermal conductances between them), and by employing the lowest surface absorptivities consistent with a given desired ratio. The latter technique is not practiced, however, since any errors in the determination of the emissivity when the emissivity is small can produce large variations in the mean temperature.

(3) The long-term variation in interior package temperatures, except for very special orbital configurations, will be at least 20 C. (Note that for the particular satellite indicated in Fig. 9 the long-term variation in temperature is roughly 45 to 50 C and hence approaches uncomfortably close to the temperature tolerances of many electronic components.)

This last factor is the major point for this digression into the thermal aspects of an Earth satellite. It is best seen in the table in Fig. 10. Here is an ideal spherical satellite with a completely uniform exterior coating. The payload is shielded thermally by radiation baffles to smooth out completely temperature variations of the exterior surface. Internal heat generation is assumed to be uniformly distributed and of such magnitude

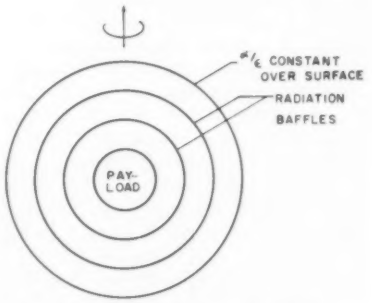


Fig. 10. Temperature dependence on fractional Sun time.

Altitude, miles	Minimum fractional Sun time	Max. % change in flux per orbit	Max. change in payload temp.*
300	.62	30	27.3° C
400	.637	29	26.3
500	.652	27	24.2
1000	.706	24	21.2

Note: Direct solar radiation taken as 0.8 of total radiation input.
* Temp. for 100% Sun period taken as 320 K.

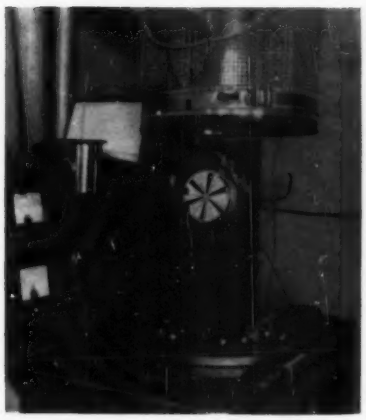


Fig. 11A. Experimental test model of the radiation heat controller.

as to reach the desired interior temperatures when the satellite is receiving the mean radiation. It is also assumed that during the time that the satellite sees the Sun, the total radiation input from all sources is constant. Hence, the only variation remaining is the change in the received flux over an orbit due to the changing ratio of the duration of the orbital day to orbital night induced by the orbit precession. The table on the figure indicates that the payload of a satellite in a circular orbit at 300 miles must still undergo a 27-degree C change in temperature under ideal conditions. At one thousand miles this variation is still above 20 C.

Any change in the α/ϵ (α, effective solar absorption; ϵ, effective thermal emissivity) ratio of the surface, whether it be due to original errors in measurements, deterioration of the surfaces under radiation and micrometeorite bombardment, ground handling or deposition, will cause a greater excursion from the mean temperature. For this ideal vehicle the change is of the order of 10 C per change of 0.1 in α/ϵ ratio.

To this point satellites with only passive thermal controls have been discussed. For the designer of equipment with limited temperature tolerances, this could represent an insoluble difficulty. Most of the operational failures of satellites in orbit have been credited to improper temperature regimes. Fortunately, however, there are developments in progress at many laboratories on active thermal control systems which will reduce the thermal problem. One such system which is being developed by our group is a variable α/ϵ device. Credit should be given to Sputnik II (they did it first), and to Dr. R. Hanel of NASA, who showed the authors his version.

Figure 11A shows an experimental test model of the radiation heat controller. The prominent features are a pie-shaped segmented wheel coated alternately by a very high α/ϵ material (SiO-Al-SiO-

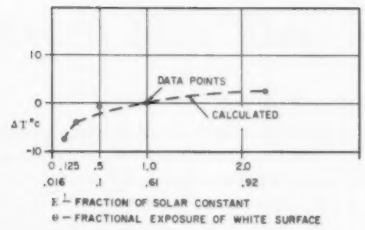


Fig. 11B. Graph of radiation heat controller action under large variation in the radiation input.

Al) and a low α/ϵ material (Rokide, Al_2O_3). The temperature sensing actuating device is a bimetallic spring which drives a shutter to control the relative exposure of the black and white surfaces. The graph shown in Fig. 11B indicates the capability of the device to maintain a reference temperature under a large variation in the radiation input. A variation in radiation input of 16 to 1 produces temperature changes of less than $\pm$ 5° in the interior of the device. By way of comparison, the equivalent device employing fixed surfaces would experience a temperature change of several hundred degrees centigrade for such a large variation in radiation input.

System Reliability

System reliability is an important additional consideration in satellite design. It should not be attributed to the environment per se. The satellite is not the place for a good system to break down. Maximum reliability can be built into the system, but only at the cost of size, weight, power, performance, capacity, etc. Trade-off's in these factors must be made all along the line.

A prime technique for obtaining reliability is to provide completely redundant systems — from power supplies, control clocks, sensors, to amplifiers, recorders, transmitters and antennas. A less obvious technique is to provide the capability for each system to operate in several reduced functional modes in case of failure of components.

Engineering modifications induced by the space environment of a forthcoming satellite under current development include pressurized containers for tape recorders to insure that the lubrication of the silicone greases is preserved. Glass coatings of the solar cells are used to reduce their effective α/ϵ from 2.5 to 1. This is done both to maintain the operating temperatures of the solar cells and to prevent the interior payload from overheating. Various components are encapsulated to reduce failure rates from shock and vibration. Heat sinks for heavy heat dissipators such as transmitters are used to prevent local overheating.

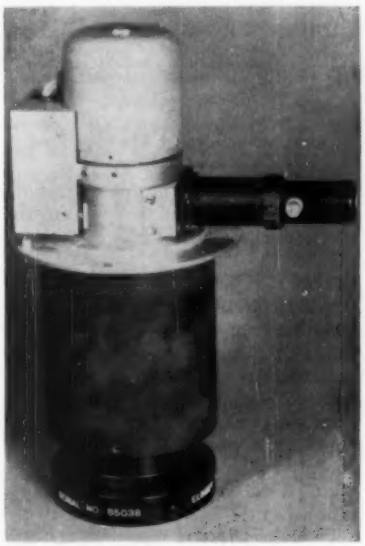


Fig. 12A. Vidicon camera system.

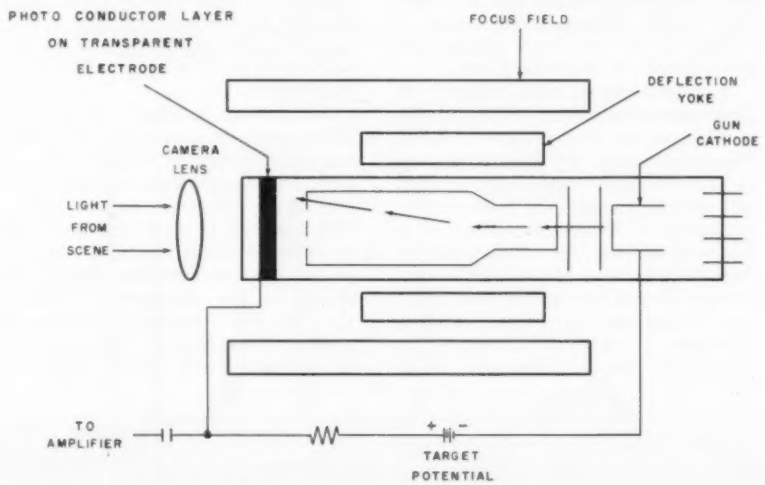


Fig. 12B. Schematic of the vidicon sensor.

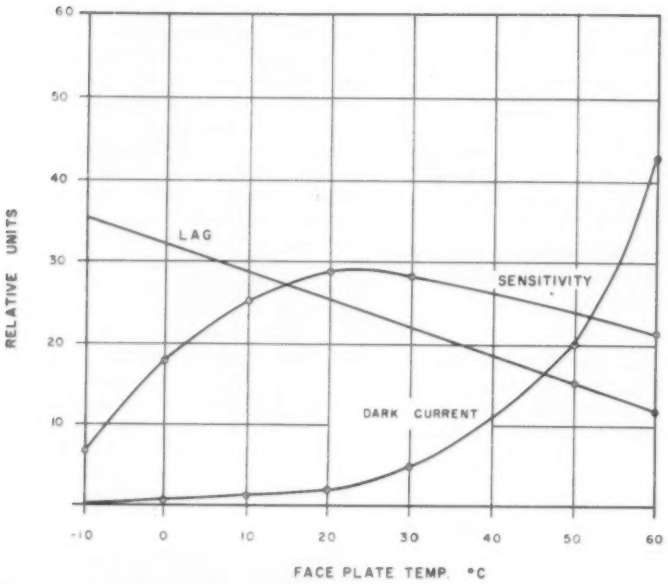


Fig. 13. Temperature characteristics of the vidicon.

Environment-Induced Modifications of a Satellite-Borne Vidicon

The final portion of this discussion is limited to the effects of the space environment on an important image sensor, the vidicon.

The vidicon is a photoconductive television pickup tube which was initially designed to operate at a 1/30-sec frame time in a television type of presentation. It has been found that the vidicon can also be used at greatly reduced scanning rates, a feature which makes possible the reduction of bandwidth and, consequently, a similar reduction in required transmitter power. Since power is a premium aboard any of the space vehicles, this feature is of utmost importance. Figure 12A shows the vidicon camera system. The more obvious features are the optics and the clock-controlled relay shutter. The vidicon is located in the top dome. Figure 12B is a schematic of the vidicon sensor.

A vidicon system with magnetic or electrostatic storage capabilities makes possible the use of a shutter for image immobilization. This feature is required in spin-stabilized (spinning) vehicles, and also, to a somewhat lesser degree, with attitude stabilization where it is necessary to stop the motion due to attitude correction. For a satellite spinning at 12 rpm, an exposure time of 1.5 msec is sufficient to reduce smear to one-third of a picture line out of the total of 500 line. Translational smears are negligible for fields of view greater than one degree.

Compared to other TV sensors the vidicon is the least sensitive to adjustment of electrode voltages and may be initially adjusted with reasonable assurance that further incremental readjustments will be unnecessary.

The ruggedization of the vidicon has been a problem in tube structure design. The sensitive elements (see Figure 12B) are the filament and the fine-mesh screen which must be stretched across an aperture of approximately picture size. Ruggedized vidicons of both the one-inch and the one-half-inch size have been constructed, the latter being able to withstand a shock of 100-g and 25-g (rms) random noise vibration.

As far as radiation is concerned, experiments designed to measure vidicon reaction to radiation have proven to be negative. This places the vidicon in a satisfactory position in competition with film systems.

The manner in which the quality is deteriorated as a function of faceplate temperature may be noted in Fig. 13. Here are plotted sensitivity, dark current and lag or "stickiness" vs. temperature. The reduction of sensitivity at the temperature extremes ultimately means a poorer signal-to-noise ratio. The increase of lag at low temperatures indicates that the time required for erasing any residual image from an exposed picture after initial readout will be appreciably increased. Hence, data capacity could be degraded. The increasing current vs. temperature causes the useful dynamic range to be compressed with consequent loss in picture contrast.

Summary

In summarizing, it should be pointed out that the component designer must not only redesign sensors to preclude deleterious effects due to the environment but, more broadly, he must consider the constraints due to the satellite itself. The system designer, on the other hand, faced with a choice of several sensors possessing desirable characteristics to perform a given function, must re-evaluate such sensors not only in light of the direct effects of the environment on the operating characteristics, but also in terms of the logistics aboard a satellite and the influence of the environment on the logistics. The mere act of placing a system aboard a satellite, at least at the present time, imposes problems as formidable as those engendered by the space environment.

Consider a typical example. Suppose a system is sought to afford daylight reconnaissance from a satellite for an extended period. Of several possible systems, photographic systems would yield the highest resolution. This is a paramount consideration for reconnaissance. However, the film storage problem due to radiation and thermal fogging, and the presentation problems, of either recovering dropped packages or satellite film development and facsimile transmission, can seriously vitiate the advantages of its greater resolution.

Discussion

J. Goldheimer (ARPA Station, RCA): In talking about antifriction bearings and the effects of loss of lubricant, contamination of the surrounding areas, etc., do you have any data on what sort of partial pressures will be necessary to avoid this effect?

Mr. Ritter: I don't have the data. This comes from some work that was done by Mr. Maybarduk of our Division. The factors of temperature, degree of evacuation and specific vapor pressure all influence the rate of loss of lubricant, hence there is a considerable variation in the rate of outgassing of the many available lubricants for any specified set of conditions. It is perhaps advisable to point out that most emissive elements require vacuums harder than those permissible to preclude outgassing and hence separate envelopes for emissive elements should be used in these cases.

Mr. Staton (RCA-AEP): In relation to radiation, could you tell us a little bit about the relative susceptibility of the image orthicon to radiation as compared to other pickup tubes?

Mr. Mesner: The image orthicon would be in essentially the same position with respect to radiation as the vidicon. There is a little difference between a photoemissive and a photoconductive device, but as far as we know this difference is actually very small.

Infrared Imaging From Satellites

By R. A. HANEL
and W. G. STROUD

Infrared images of the Earth's surface and atmosphere obtained from a satellite are important to the study of the meteorology of the Earth, and present unique problems in systems design and in image conversion techniques. The known and inferred infrared properties of the Earth are the basis on which detector systems and the sensors themselves may be considered for satellite use. The improvement of sensor spectral sensitivity and response time will make possible better experiments and studies of the atmosphere in the future.

THE IMAGE of our planet in the infrared, as well as in the visible spectrum, is of special interest to meteorologists since the weather, taking place in the atmosphere, can be inspected from a point of view well above the subject. Air masses may be identified and many of the characteristics such as temperatures, clouds, composition, and water content may be determined by infrared measurements from above the air mass.

Infrared radiation, invisible to the human eye, ranges between red and microwaves in the electromagnetic spectrum. An infrared image is essentially a color picture of an enormous variety of different shades and colors, inaccessible to our eyes. An image of this colorful world translated by our instruments into black-and-white is all we can hope for.

Since the average temperature of our planet does not change appreciably over a period of a few years, incoming solar radiation and outgoing thermal radiation must balance. The amount of reflected sunlight, the albedo, has been determined by various methods. One is the measurement of the "Earth shine" reflected by the Moon; another is the computation from measured and computed values of the reflectivity of clouds, ocean and land areas. An average value of 0.36 has been accepted, yielding 250 K as the blackbody temperature of our planet (Fig. 1).

Presented on October 6, 1959, at the Society's Convention in New York City, by R. A. Hanel (who read the paper), and W. G. Stroud, Goddard Space Flight Center, National Aeronautics and Space Administration, 1520 H St., NW, Washington 25, D.C.
(This paper received first on September 9, 1959, and in final form on November 12, 1959.)

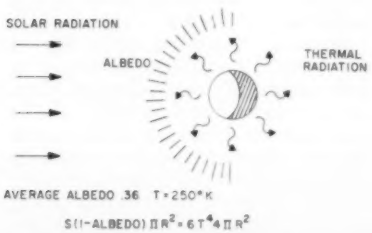


Fig. 1. Heat balance of the Earth.

Observation of Atmosphere

Unfortunately for a simple theory, but very fortunately for life on Earth, a rather complexly composed atmosphere covers the surface we live on. The albedo varies with atmospheric conditions, especially the cloudiness. Of course, the latitude also determines the amount of absorbed solar energy. The long wavelength thermal re-radiation is strongly influenced by water vapor and cloud distribution. The constantly changing weather is accompanied and largely caused by radiation exchange. A satellite outside the atmosphere is an ideal platform to observe the energy budget of our planet, especially its atmosphere. Observations can be made on a global basis. If the resolving power of our instrument is low, yielding average values over 100,000 square miles, for example, measurements are called heat balance experiments. If the resolving power is much better, 30 by 30 miles, for example, the term infrared image of the Earth is more appropriate. To understand and to interpret such an infrared "picture," the infrared properties of the atmosphere shall be examined here.

Gases making up the air mass show a high number of weak and strong absorption lines ranging from ultraviolet (ozone, oxygen, nitrogen) to the far infrared (water vapor, CO_2, ozone). Normally, atmospheric absorption is plotted versus wavelength but it is much more instructive to use energy increments as shown in Fig. 2. The abscissa is proportional to the energy available from a 300 K blackbody.

Now it becomes quite clear why CO_2 (concentration in the atmosphere 0.033%) and water vapor have such an influence on the temperature and climatic conditions of the Earth. Water vapor and CO_2 act as gigantic radiation filters between the surface and outer space. Similarly, clouds are tremendous shutters, shielding large parts of the Earth from solar radiation and preventing thermal radiation from escaping to outer space.

These filters and shutters radiate energy proportional to their own temperature in exactly the same spectral bands they absorb. A satellite-borne infrared system, sensitive to the water-vapor absorption bands only, "sees" the top of the vapor layer, a fact which may be used to measure the temperature and humidity of the upper limit of the troposphere. A detector, sensitive to the "window," sees through the moist air and can measure ground or cloud top temperatures. Since clouds are generally cooler than the Earth's surface, an infrared image in the 8- to 12-μ region may yield a nighttime cloud cover picture. Thus, infrared maps of the Earth taken at various spectral bands provide useful information to meteorologists and geophysicists.

In preparation is a meteorological satellite project which will incorporate the use of infrared sensors. Besides television cameras for daytime cloud cover and a low-resolution heat balance experiment, the satellite will scan the earth with medium resolution of about 30 by 30 miles in five spectral regions. Those regions are:

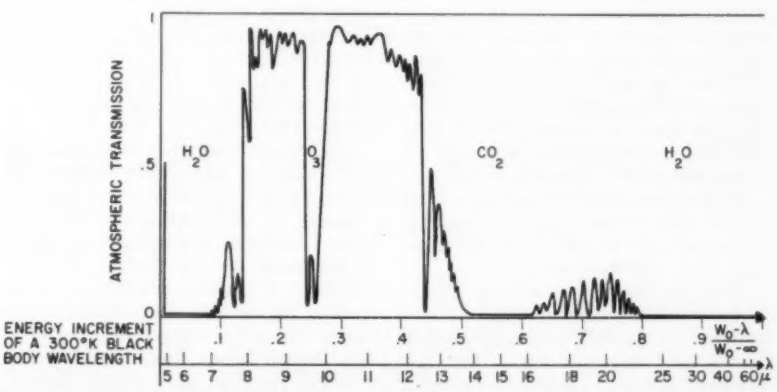

ATMOSPHERIC TRANSMISSION
1
.5
0
H₂O
O₃
CO₂
H₂O
ENERGY INCREMENT OF A 300°K BLACK BODY WAVELENGTH
.1 .2 .3 .4 .5 .6 .7 .8 .9
5 6 7 8 9 10 11 12 13 14 15 16 18 20 25 30 40 60μ

Fig. 2. Atmospheric transmission.

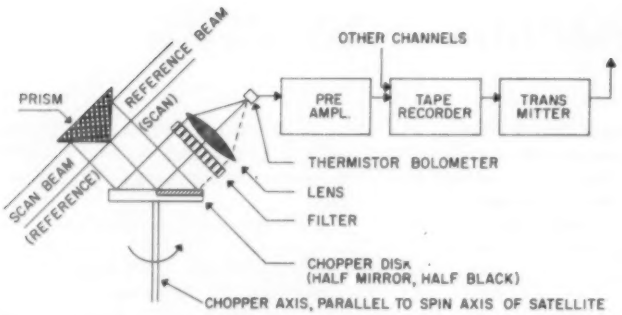


Fig. 3. The scanning channel of the five-channel radiation experiment.

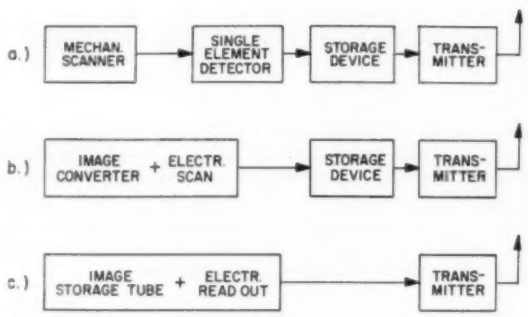


Fig. 4. Infrared imaging systems.

0.2- to 5-μ — About 99% of solar radiation falls into this spectral band.

7- to 40-μ — This channel measures the blackbody temperature.

8- to 12-μ — The atmospheric window yields surface temperatures as well as day and night cloud cover.

5.6 to 7-μ — Strong water vapor absorption characterizes this channel.

0.55- to 0.75-μ — A reference close to the spectral response of the eye and to near infrared photography was introduced. It should be very helpful in the interpretation of the other channels and will also yield daytime cloud cover.

It is common technique in the field of radiometry to compare radiation to be measured to a reference blackbody of known temperature. In a satellite this would require quite an effort to stabilize the temperature of such a reference considering the limited power available. A satellite-borne radiometer, however, can use outer space as a cold reference if Sun, Earth, and Moon are not in the field of view. This approach has been chosen in the meteorological satellite mentioned above. One out of the five channels, being part of the scanning experiment, is shown in Fig. 3.

The disc chopper, half-reflecting, half-absorbing, switches radiation from the scan beam and the reference beam alternately to the detector. Consequently, the alternating voltage generated at the detector is proportional to the energy difference between the two beams. Thermal radiation from the chopper disc, the filters and the lens does not contribute to the alternating signal since they are in the field of view all the time. Proper lens and filter materials have to be chosen to accommodate the various spectral ranges.

R. Astheimer and A. Kaufman from Barnes Engineering Company made a substantial contribution to the development of the radiometer head.

The signal from the detector is converted and finally stored on magnetic tape by means of a specially designed miniature high-fidelity tape recorder. When the satellite passes over a readout station the information is telemetered back to Earth.

This instrument is an example of the spot-scanning technique. The concept corresponds to the Nipkow disc scanner in the days of earliest television and picture telegraphy. We used it on the Vanguard II satellite. The detector-optics are fixed with respect to the spin axis of the satellite, and as the satellite spins the optic views the Earth in line-by-line consecutive sweeps. On the ground the lines are reconstructed into a picture.

For worldwide coverage some means of storage within the satellite must be provided, otherwise an unreasonable number of telemetering stations, scattered over the whole world, is necessary. A variety of systems capable of infrared imaging can be visualized.

Techniques of Scanning and Detecting

The function of the mechanical scanner and the detector can be performed by an image-conversion tube and an electronic scan system, at least in the near infrared and visible part of the spectrum (Fig. 4). The vidicon is such an image converter; it is used in a meteorological satellite to show cloud distributions during daylight hours.

The next step would be to incorporate the storage function in the tube. Image-storage tubes for signal frames or even for a number of frames may replace in time the mechanical scanner and the tape recorder, eliminating most of the moving parts in the satellite itself. Unfortunately, the method is today restricted to the near infrared. In the most interesting part of the spectrum, from 5 to 50μ, spot-scanning techniques prove to be the best approach for gathering an image of the Earth.

Two types of single-element detectors are commonly used, thermal detectors and photoconductors. The first category depends on the heating power of infrared radiation, in contrast to the latter being based on the freeing of bound electrons by quantum absorption.

Photoconductors show higher sensitivity and better signal-to-noise ratio in the near infrared. From about 8μ on, thermal detectors are superior. Recent developments in the field of doped germanium crystals, however, seem to shift the limit to longer wavelength.

A number of other factors influence the choice of detector. Time constant is a consideration for high-speed scanning systems as well as for cooling requirements. Photoconductors, especially those for longer wavelength, require a very low operating temperature (−195° C liquid nitrogen, for example) and even lower, depending on the cutoff wavelength. On the other hand, in outer space a type of cooling rather ineffective at the Earth surface can be used — cooling by radiation. A body of high emissivity, shielded from the Sun, Earth and Moon will adjust itself to an equilibrium temperature in the order of 50 to 150° K depending on the thermal isolation from the main satellite. From here on, the inverse thermal electric effect, i.e. the Peltier effect, can be used to lower the temperature further.

A relatively simple low-power cooling system capable of holding the infrared detector at a constant temperature below 80° K over a period of six months will be needed to make full use of long wavelength photoconductors in satellites.

Many refinements over instrumentations such as these will be made in the future. The resolving powers of infrared systems of the scanning type as well as the image-forming type must be improved. Developments in this field must conform with progress in the area of information storage and communication capabilities. For example, four times the information bandwidth is required just to double the resolution.

Very promising aspects will be opened by increased spectral resolution. For example, a method of determining the temperature profile of the atmosphere based on a spectral analysis of the 15-μ CO_2 band has been proposed.

Stereoscopic pictures, taken by the same satellite only a few seconds apart, may yield cloud altitudes and will aid in the interpretation of cloud types.

In time, infrared imaging devices developed as special tools for meteorologists and geophysicists will help to advance our knowledge of climatic conditions and physical properties of other planets within our solar system.

Pictorial Data Transmission From a Space Vehicle

By J. F. BAUMUNK
and S. H. ROTH

Space communications are essentially line-of-sight transmissions complicated by nonstationary terminals and the literally astronomical distances involved. Severe limitations on available power and weight restrict transmitter power, and therefore narrow bandwidths for transmission of pictorial data are required. These unique conditions underlie certain problems and possible solutions.

MANY OF THE PROBLEMS of communication with a space vehicle are not in themselves unique because they are primarily line-of-sight communication. The combination of these problems related to space-vehicle communications is, however, rather unusual, and possible solutions to meet both present and future requirements are of interest to both the communication and television engineer. Major problems include the literally astronomical distances involved; nonstationary terminals which may be moving many tens of miles per second relative to each other; and bandwidth restrictions consistent with the power restrictions. These areas are closely related in that efficient use must be made of the available bandwidths with modulation schemes that do not necessitate overly complex equipment. There are also the apparently conflicting requirements that the equipment must be very reliable as well as light in weight and small in size.

Design Considerations

One of the first considerations is that of choosing a carrier frequency. For space communications, a frequency high enough to penetrate the ionosphere must be used. There is a great deal of man-made noise below 30 mc, as well as cosmic noise at higher frequencies. At higher and higher frequencies, the noise continues to drop until, between 10 and 20 kmc, the noise level again rises due to the water vapor. Figure 1 illustrates the noise temperatures and their sources. From the graph it may be concluded that frequencies for communications purposes must be between approximately 150 mc and 10 kmc. The choice within these limits depends upon the power requirements and the state of the art. For example, in a low-power space-vehicle transmitter, one might look to solid state devices for reliability and efficiency, a choice which then limits the frequency to the few-hundred-megacycle range. As devices of higher frequencies are improved for space use, higher frequencies will be used. The present state of the art, in fact, indicates that the 1000-mc range is an optimum choice for some systems. The one important factor that should influence any system design for space communication is reliability. The most sophisticated theoretical system is worthless if it is not reliable, so that it is far better to have a basically simple system with emphasis on reliability.

A considerable variety of television systems may be used in space probes; some may bear little likeness to what is commonly called television. It is beyond the scope of this paper to discuss pickup devices, scanning modes and methods, and storage equipment. The scanning devices may be electrical or mechanical, or both, and the storage device may be a vidicon or some form of tape storage. The communication problem may be described adequately by discussing the image in terms of the number of picture elements. Since one cycle will describe two picture elements, the product of frequency bandpass and time of transmission is a constant for any picture of given resolution. This permits the trading of bandwidth for time of transmission.

The determination of required signal-to-noise ratios depends on the overall system requirements and in many instances is made on a subjective basis. Fig. 2 is a 500-line picture of what may be expected to be seen on the surface of the Moon with a 10-db signal-to-noise ratio. The signal-to-noise ratio is defined in this paper as 20 log (peak-to-peak video voltage/2 rms noise voltage). It is noted that, although for some applications this may be adequate, it leaves something more to be desired. Figure 3 is the same subject with a 20-db signal-to-noise ratio. These pictures were taken with an exposure of one frame and are not as good as visual observation of the same signal-to-noise ratio at standard television rates. This is because the eye tends to integrate the noise and signal over several frames when viewing standard television. One can also determine the required signal-to-noise ratio in terms of the required number of distinguishable gray levels and object size. In this case, the noise-power spectrum and the first and second order statistics of the noise must be taken into account.

Power consumption economy and circuit simplicity usually govern the type of modulation to be used. Narrow-band FM has several advantages; one advantage is the noise improvement factor due to the shape of the output noise spectrum. This results in a lower transmitter power. Other advantages are the comparatively low modulating power required, the relative simplicity of FM transmitter circuits, and the capability of wide dynamic range, where it is required.

In comparison, pulse-modulation tech-

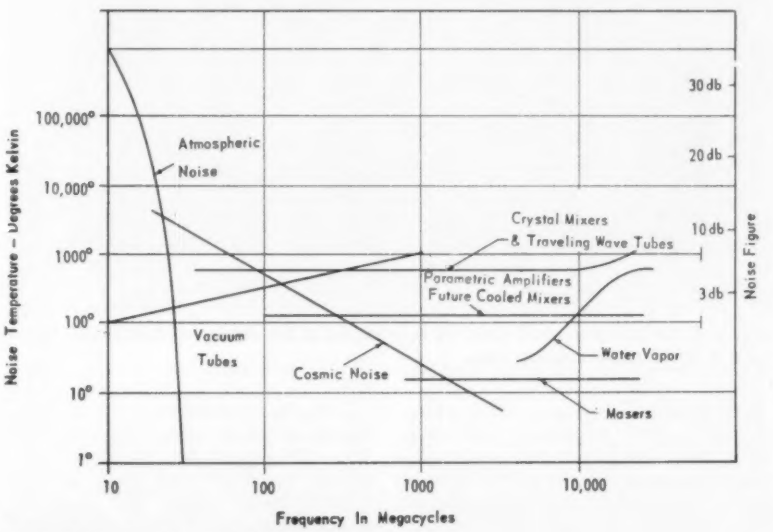
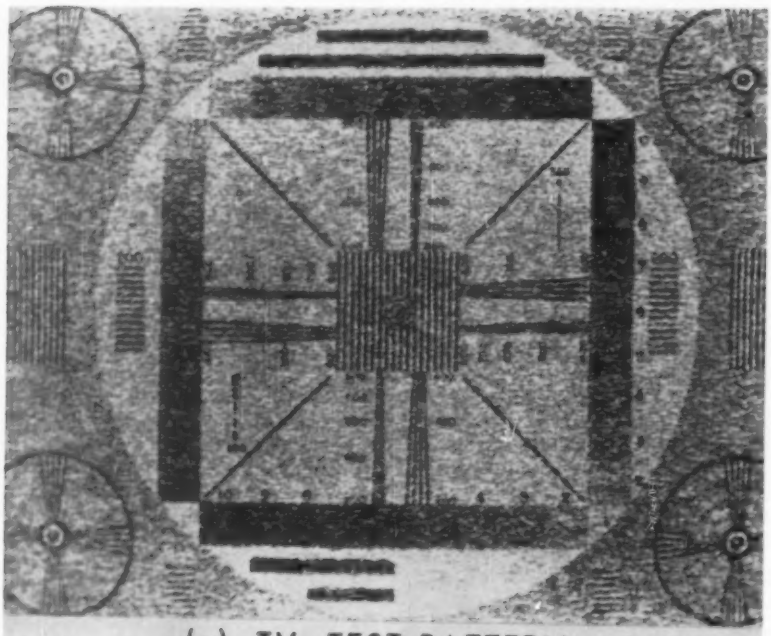


Fig. 1. Noise densities and their sources.

Presented on October 6, 1959, at the Society's Convention in New York City, by J. F. Baumunk (who read the paper) and S. H. Roth, Astro-Electronic Products Div., Radio Corp. of America, Princeton, N.J.
(This paper received first on September 4, 1959, and in final form on December 7, 1959.)



(a) TV TEST PATTERN

(b) TV PICTURE OF MOON

Fig. 2. A 500-line picture of what we may expect to see on the surface of the Moon with a 10-db signal-to-noise ratio.

niques require larger bandwidth or more circuitry; AM requires considerably more modulator power, and single sideband, much more circuitry. Phase modulation has many of the advantages of FM, but does not have the noise improvement capability.

The slow transmission rate requires that the system be essentially d-c coupled. In an FM system the Doppler-shift frequency variations would act the same as a low-frequency signal. The amplitude of this variation is directly proportional to the frequency shift and can be quite large. From the series expansion relating the Doppler shift to the radial velocity of the two terminals, it is seen that the higher-order terms can be neglected when the radial velocity is small compared to the speed of light. For example, a change in vehicle velocity of 1 mile/sec would produce a shift of 5.4 kc in the case of a one-kmc carrier.

$$f^1 = f\left(1 \pm \frac{V}{c} \pm \tfrac{1}{2}\frac{V^2}{c^2} \pm \tfrac{1}{2}\frac{V^3}{c^3} \ldots\right)$$

where

c = velocity of light,
V = radial velocity of vehicle,
f = original frequency, and
f^1 = shifted frequency;

for

$$c >> V,$$

$$f^1 = f\left(1 \pm \frac{V}{c}\right),$$

and

$$\Delta f = \pm f\,\frac{V}{c};$$

if

f = 1 kmc,
V = 1 mile/sec, and
Δf = 5.4 kc.

In most cases variations of this order would be intolerable. Phase or amplitude modulation is of no help since there is no d-c capability. Digital pulse modulation does have d-c capability, but the large bandwidth requirements make it unattractive. The problem is solved by the use of a subcarrier. The information signal modulates the subcarrier which in turn modulates the carrier. FM is generally used for the subcarrier for the same reasons that apply to the carrier. The Doppler shift of the subcarrier follows the same relationship as that of the carrier; however, its center frequency is many orders of magnitude less than the carrier, giving a corresponding reduction in Doppler variation.

Transmission From a Satellite in the Vicinity of the Moon

To illustrate the design of a communication system for space-television transmission, let us look at a very realistic problem such as the transmission of a picture from a station in the vicinity of the Moon. The picture to be transmitted is square and scanned with 500 lines in a conventional manner. It is also desired to maintain 500-line resolution. The readout rate of the picture is one frame per minute. We may also choose, based on the previous discussion, a signal-to-noise ratio at base band of 20 db.

The bandwidth requirement is:

$$BW = \left(\frac{\text{No. of picture elements}}{2 \times \text{time in seconds}}\right)$$

or

$$BW = \frac{500 \times 500}{120} = 2100 \text{ cps.}$$

An FM/FM modulation scheme with the following parameters is selected:

Subcarrier frequency.....5000 cps
Modulation index (subcarrier)..1
Video base-band bandpass.....0–2100 cps
Carrier frequency.....1 kmc
Modulation index.....1
Intermediate-frequency bandwidth.....20 kc

The signal-to-noise ratio at the output of an FM/FM system is (see Appendix):

$$\frac{S}{N} = \frac{C\sqrt{B}F_1 F_2}{N_{if}\sqrt{2}\left[\frac{f_2^5}{5} - \frac{f_{sc}f_2^4}{2} + \frac{f_{sc}^2 f_2^3}{3} - \frac{f_1^5}{5} + \frac{f_{sc}f_1^4}{2} - \frac{f_{sc}^2 f_1^3}{3}\right]^{1/2}}$$

where

$\frac{S}{N}$ = rms signal voltage-to-rms noise voltage ratio,
$\frac{C}{N_{if}}$ = rms carrier voltage-to-rms noise voltage in the i-f amplifier,
B = bandwidth of i-f amplifier,
F_1 = r-f carrier peak deviation,
F_2 = subcarrier peak deviation,
f_{sc} = subcarrier center frequency,
f_m = cutoff frequency of video output circuits,
$f_1 = f_{sc} - f_m$, and
$f_2 = f_{sc} + f_m$;

substituting:
$B = 2 \times 10^4$,
$F_1 = 7 \times 10^3$,
$F_2 = 2.1 \times 10^3$,
$f_{sc} = 5 \times 10^3$,
$f_m = 2.1 \times 10^3$,
$f_1 = f_{sc} - f_m = 2.9 \times 10^3$, and
$f_2 = f_{sc} + f_m = 7.1 \times 10^3$.

We find that the required signal-to-noise ratio in the i-f passband is 3.6 or 11 db.

The noise power in the i-f passband referred to the receiver input is given by

$$P_n = KT_eB$$

where

P_n = noise power,
K = Boltzmann's Constant,
T_e = effective noise temperature (K), and
B = i-f bandwidth.

The effective noise temperature (T_e) is made up of two components; the effective temperature at the antenna terminals (T_a) when connected to a perfect noiseless receiver and T_r the effective noise temperature of the receiver referred to the input of the receiver when connected to a perfect noiseless antenna. By superposition

$$T_e = T_a + T_r.$$

For this example a 2-db noise figure receiver was chosen. This can be achieved by the use of a parametric amplifier preceding a conventional low-noise i-f amplifier. The effective temperature of the receiver can be computed from the relationship

$$T_r = 293\,(NF - 1),$$

where

NF = noise figure of the receiver.

For a 2-db receiver

$NF = 1.6$, and
$T_r = 293\,(1.6 - 1) = 175$ K.

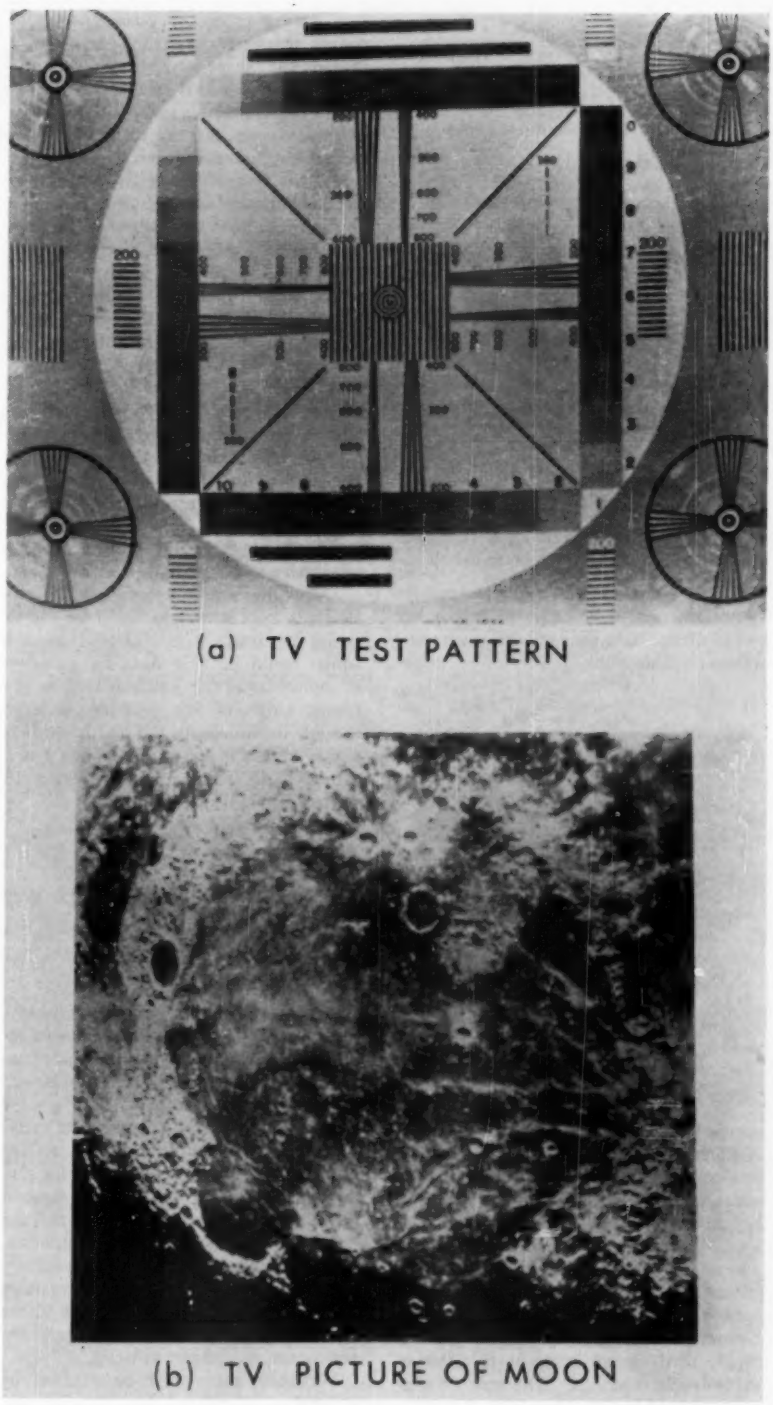


Fig. 3. Same as Fig. 2, with a 20-db signal-to-noise ratio.

The antenna temperature is determined by the amount of random radio energy received from space and through side lobes oriented toward the relatively "hot" Earth. There is also a contribution due to losses in the antenna and the transmission lines to the receiver. The actual noise temperature is a function of the direction of the antenna beams, but a good approximation can be made of about 100 K, providing the side lobes are well suppressed and the beam is not pointing at a particular "hot" source such as the Sun. The total effective noise temperature for this example is then

$$T_e = 100 + 175 = 275 \text{ K}$$

Table I. Specifications.

Picture resolution	500 × 500 lines
Number of elements	250,000
Transmission time	1 min
Base band	2100 cps
Range	250,000 miles
Receiver	
Intermediate-frequency BW	20 kc
Noise figure	2 db
Antenna	60-ft dish
Gain of antenna	43 db
Transmitter	
Carrier frequency	1 kmc
Type modulation	FM
Peak deviation	± 7 kc
Antenna	crossed dipoles circularly polarized
Antenna gain	−3 db
Subcarrier	
Center frequency	5 kc
Type modulation	FM
Peak deviation	± 2.1 kc

and the noise at the input of the receiver is

$$P_n = KT_sB = 1.36 \times 10^{-23} \times 2 \times 10^4 \times 275 = 7.5 \times 10^{-17} \text{ w or } -161 \text{ dbw.}$$

This means that the receiver power (P_r) must be −161 dbw + 11 db or −150 dbw. Using the well-known transmission equation

$$\frac{P_r}{P_t} = \frac{G_tG_r\lambda^2}{(4\pi d)^2}$$

where

G_t = gain of the transmitting antenna over an isotropic antenna,
G_r = gain of the receiving antenna over an isotropic antenna,
λ = wavelength, and
d = distance in the same units.

For the system described:

$$d = 250{,}000 \text{ miles} \times 1.609 \times 10^3 = 4.02 \times 10^8 \text{ m},$$

$$\lambda = \frac{300}{1000} = 0.3 \text{ m}$$

$$\therefore \frac{P_r}{P_t} = \frac{(3 \times 10^{-1})^2}{(4\pi \times 4.02 \times 10^8)} G_tG_r = [0.351 \times 10^{-20} G_tG_r]$$

$$\frac{P_r}{P_t} = -204.5 \text{ db} + G_{t\,(\text{db})} + G_{r\,(\text{db})},$$

or the loss between isotropic antennas is 204.5 db. Choosing from reasonable and available antenna systems, the ground antenna is a 60-ft dish with vertical and horizontal feeds and polarization diversity. The expected gain of such an antenna is 43 db. This does not constitute the highest-gain antenna in existence, but an available size. The vehicle antenna is a circularly-polarized crossed dipole used in an attempt to achieve an isotropic antenna. The gain of this antenna will be about −3 db. Then:

$$\frac{P_r}{P_t} = -204.5 - 3.0 + 43.0 \backsimeq -165 \text{db.}$$

Therefore, if the power received must be −150 dbw, the transmitter power required is −150 dbw −(−165 db) or 15 dbw. Allowing a 10-db margin for equipment deterioration and nonoptimum operating conditions, makes the transmitter power 25 dbw or approximately 300 w, which still seems like a rather high power especially considering that the efficiency may be in the order of 20%, making the power requirement 1500 w.

One of the obvious ways to reduce the power requirement is to increase the time of transmission, but the total energy required for the transmission of one picture is still the same. The weight and size of the transmitter are reduced, however, to that of a 30-w transmitter if the time is increased, for instance, to ten minutes. However, there may be some advantage as a function of realizable efficiency, in using one, rather than the other, transmitter provided either transmission time is acceptable.

A more advantageous solution is obtained by increasing the gain of the antenna system. Some vehicles may be stabilized to maintain the optical axis orientation, in which case it may be feasible to use a directional instead of the isotropic antenna. This antenna would be even more feasible if the space probe were to land on the Moon.

Since the angle subtended by the Earth is approximately 1.8°, the Earth could be tracked by infrared sensors which could provide data for pointing at the center of the Earth as long as the beam width of the antenna is large enough to illuminate the Earth. An example of this is a 5-ft dish which has a gain of 21 db. The beam angle is given in degrees by

$$\theta = \sqrt{\frac{27{,}000}{G}}$$

where G is the gain of the antenna or in this case 125. Therefore

$$\theta = \sqrt{\frac{27{,}000}{125}} = 14.7°$$

This is a reduction of power required by 21 db−(−3 db) or 24 db. The power required with the isotropic antenna was 25 dbw or 300 w, but now is 25 − 24 = 1 dbw which is 1.25 w. This is a very reasonable power requirement and within the present state of the art for using solar cell power supplies. This saving must, however, be weighed against the increased power consumption and the weight required to track the antenna, which depends upon the particular probe (since some probes lend themselves more easily to antenna stabilization by virtue of the requirements of the primary experiments aboard the vehicle).

This same gain could be realized by increasing the gain of the ground receiving antenna, but it would require a dish well over 600 ft in diameter to effect the same gain as the 5-ft dish on the vehicle. Table II illustrates the energy required for each picture for the different component selections.

Table II. Energy Required for Each Picture.

Time of transmission (one frame)	Radiated power, w	Input power (at 20% efficiency)	Total energy, whr	Antenna gain, db
1 min	300	1500	25	$G_t = -3$ $G_R = 43$
10 min	30	150	25	$G_t = -3$ $G_R = 43$
1 min	1.25	6.25	0.105	$G_t = 21$ $G_R = 43$

Conclusion

This discussion is not intended to provide fixed rules for the design of a communication system for space vehicles, but rather to point out some of the major areas to be considered. It has, however, illustrated the practicality of instrumenting such a system. The actual configuration of a system will depend on the mission and payload capabilities. General conclusions can, however, be made: such as the advantage of using FM subcarriers for video transmission. Higher carrier frequencies will be used because of the lower noise level and increased antenna gain as practical equipment becomes available. It will then be very helpful to use low-noise amplifiers such as the maser.

APPENDIX

Derivation of Signal-to-Noise Ratio at the Output of an FM/FM System

A block diagram of the detection system is shown as Fig. 4.

It is assumed that, in both detectors, the carrier-to-noise ratio is greater than the threshold value. With good limiting this value is approximately 12 db.

At the output of the i-f amplifier the noise voltage at frequency f_n will have the equivalent value

$$C_n = \sqrt{K2\,\Delta f_n}\cos 2\pi f_n t,$$

where

f_n = any frequency within the bandpass of the i-f,
K = noise power density per unit bandwidth at the output of the i-f, and
Δf = a small increment of bandwidth.

The carrier voltage at the output of the i-f has the value

$$C_c = \sqrt{2}\,C \cos 2\pi f_0 t,$$

where

C = rms carrier voltage, and
f_0 = carrier frequency.

Since C is at least 12 db greater than the total noise in the i-f, it is safe to state

$$C >> \sqrt{K\,\Delta f},$$

where

$\Delta f << B$, and
B = i-f bandwidth;

then

$$\sin\alpha = \frac{\sqrt{K}\,\sqrt{\Delta f}}{C}\cos 2\pi (f_0 - f_n)t, \quad (1)$$

where α = angle between the carrier alone and the resultant of the carrier and the noise voltage at frequency f_n, as shown in Fig. 5.

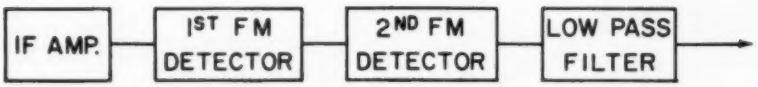


Fig. 4. Block diagram of the detection system.

Since

$$\frac{\sqrt{K\,\Delta f}}{C} << 1,$$

then

$$\alpha \backsimeq \frac{\sqrt{K\,\Delta f}}{C} \cos 2\pi (f_0 - f_n)t. \quad (2)$$

α is then the angular modulation due to noise voltage e_n.

The equivalent frequency modulation is

$$\frac{1}{2\pi}\frac{d\alpha}{dt} = -\frac{\sqrt{K\,\Delta f(f\alpha)}}{C} \sin 2\pi f_\alpha t, \quad (3)$$

where $f\alpha = |f_0 - f_n|$.

There will be two components of noise at frequency f, one from $f_\alpha = f_0 + f$ and the other from $f_\alpha = f_0 - f$. Therefore, limiting f_α to positive values the FM noise modulation is

$$C_m = \frac{\sqrt{2K\Delta f}}{C} f_\alpha \sin 2\pi f_\alpha t, \quad (4)$$

where $f_\alpha = |f_0 - f_n|$.

The subcarrier signal voltage is

$$C_{sc} = F_1 \sin 2\pi f_{sc}\, t,$$

where

F_1 = peak deviation of subcarrier signal on the carrier, and
f_{sc} = subcarrier frequency.

Then, as previously shown (Eq. 2), the angular noise modulation on the subcarrier will be

$$\alpha_1 = \frac{\sqrt{2K(\Delta f\alpha)f_\alpha}}{CF_1} \sin 2\pi (f_{sc} - f_\alpha)t. \quad (5)$$

The FM noise component is

$$\frac{1}{2\pi}\frac{d\alpha_1}{dt} = \frac{2\,K\Delta f_\alpha\,(f_\alpha)\,(f_{sc} - f_\alpha)}{CF_1} \cos 2\pi (f_{sc} - f_\alpha)t \quad (6)$$

To obtain the total noise in the final video passband it is necessary to integrate Eq. (6) over the limits

$$\begin{aligned} &\text{from } f_\alpha = f_{sc} - f_m \\ &\text{to } f_\alpha = f_{sc} + f_m, \end{aligned}$$

where f_m is the highest signal frequency modulation component on the subcarrier. This assumes that a low-pass filter is used at the output of the second detector with cutoff frequency f_m.

Then, letting
$f_1 = f_{sc} - f_m$, and
$f_2 = f_{sc} + f_m$,

the total rms noise voltage in the output is

$$\left[\int_{f_1}^{f_2}\left(\frac{\sqrt{2K\Delta f(f_\alpha)}}{CF_1}(f_{sc} - f_\alpha)\right)^2 df_\alpha\right]^{1/2} \quad (7)$$

$$= \frac{\sqrt{2K}}{CF_1}\left[\int_{f_1}^{f_2}(f_\alpha(f_{sc} - f_\alpha))^2\, df_\alpha\right]^{1/2}$$

$$= \frac{\sqrt{2K}}{CF_1}\left[\frac{f_2^5}{5} - \frac{f_{sc}f_2^4}{2} + \frac{f_{sc}^2f_2^3}{3} - \frac{f_1^5}{5} + \frac{f_{sc}f_1^4}{2} - \frac{f_{sc}^2f_1^3}{3}\right]^{1/2}$$

The signal voltage at the output of the second detector is

$$\rho_s = F_2 \sin \omega t,$$

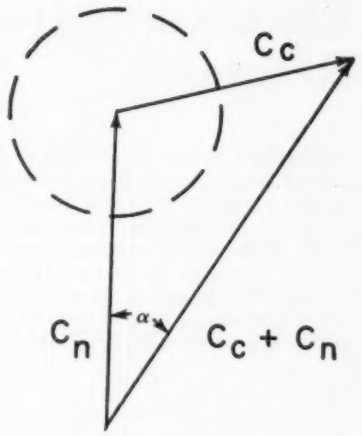


Figure 5

where

F_2 = peak deviation of signal on subcarrier.

Therefore signal-to-noise in the output is

$$\frac{S}{N} = \frac{F_1F_2C}{\sqrt{2K}\left[\frac{f_2^5}{5} - \frac{f_{sc}f_2^4}{2} + \frac{f_{sc}^2f_2^3}{3} - \frac{f_1^5}{5} + \frac{f_{sc}f_1^4}{2} - \frac{f_{sc}^2f_1^3}{3}\right]^{1/2}} \quad (8)$$

Since

K = noise power density in the i-f,

$$\frac{S}{N} = \frac{C}{N_{i-f}}\frac{F_1F_2\sqrt{B}}{\sqrt{2}}\frac{1}{\left[\frac{f_2^5}{5} - \frac{f_{sc}f_2^4}{2} + \frac{f_{sc}^2f_2^3}{3} - \frac{f_1^5}{5} + \frac{f_{sc}f_1^4}{2} - \frac{f_{sc}^2f_1^3}{3}\right]^{1/2}} \quad (9)$$

where

N_{i-f} = rms noise voltage in i-f.

Electrostatic Imaging and Recording

By E. C. HUTTER, J. A. INSLEE and T. H. MOORE

Simultaneous pickup and electrostatic storage of optical information are accomplished by using a transducer consisting of a pickup tube with a layer of photoconductor overlaid by a thin layer of highly insulating material. Recording is achieved by simultaneous optical exposure of the photoconductor and electronic beam contact to the insulator. A charge pattern corresponding to the optical pattern remains on the insulator. During the storage period, which may be for several days, the target is insensitive to light and radiation. When readout is desired, the charge image is read by an electron beam, as in a television pickup tube. The images may be stored on fixed targets or on a flexible tape.

THE ABILITY to put instrument packages into orbit provides a wide range of possibilities for obtaining data about the Earth and its environment. One of the most useful types of information which can be so obtained is pictorial — for mapping some of the remote portions of the Earth or for preparing a daily photographic weather map of the entire Earth.

A satellite camera to perform these or similar functions must have several special characteristics, among the most important of which are:

(a) high light sensitivity, preferably in the red portion of the visible spectrum,
(b) ability to store the pictorial information for the duration of at least one orbit, and
(c) means of transmitting the information to the ground via radio.

Sensitivity in the longer visible wavelengths is desirable to achieve maximum haze penetration. The pictorial information must be stored for at least one orbit, because the satellite spends most of its time out of transmission range from a given ground station. For orbits of approximately 300 miles the orbital period is about 90 min, and the satellite is above the horizon for a given ground station for a maximum time of only about 10 min. Pictures taken during 80 min of the orbit must be stored until the ground station is within radio range.

Some other requirements of the camera are:

(d) operation in vacuum,
(e) operation in Van Allen radiation,
(f) unattended operation,
(g) operation with great reliability for a very long time,
(h) consumption of a minimum of power with minimum weight, and
(i) high resolution.

It was specifically for satellite applications, and to meet the above requirements, that the electrostatic imaging and recording system was first developed.

Presented on October 6, 1959, at the Society's Convention in New York City, by E. C. Hutter (who read the paper), J. A. Inslee and T. H. Moore, Astro-Electronic Products Div., Radio Corp. of America, Princeton, N. J.
(This paper received first on September 4, 1959, and in final form on November 12, 1959.)

Basic Operation

The transducer consists of a pickup device with electron guns and conventional focusing and deflection coils, but with a target consisting of a transparent support, a transparent backing electrode, a high quantum efficiency photoconductor, and a layer of insulator. This target, when in the form of a flexible tape, will hereafter be called a "phototape" (Fig. 1). The transparent support presently used is du Pont Cronar* motion-picture film base. The transparent backing electrode is a thin evaporated film of gold, chromium or other suitable metal, and the photoconductor used for sensitivity in the visible red is antimony trisulfide, the same chemical compound that is used in commercial vidicons. The insulator layer used at present is pure polystyrene. On each side of the sensitive area of the tape is a metal strip which serves as an electrical contact to the backing electrode. It is possible for this metal strip also to serve as a spacer to prevent physical contact between adjacent layers of tape on the storage reel.

A schematic drawing of a phototape camera and a lumped-constant electrical equivalent circuit are shown in Figs. 2A and B. The electron beam functions as a switch and is so shown. In step 1, a potential difference V is applied across the series R-C circuit formed by the photoconductor and insulator layers of the phototape. This potential is applied through an electron flood beam, and the photoconductor can be either in darkness or uniform light. The contact is maintained for a period of time equal to many time constants of the series R-C circuit. At the end of this period, a uniform potential difference equal to the applied voltage V is established across the insulator layer. The electron flood beam is turned off and the applied voltage is reduced to zero. Now all remnants of previous pictures are removed from the insulator, and the tape is ready for optical exposure.

In step 2, an optical image is projected onto the photoconductor, and simultaneously the electron flood beam makes contact with the surface of the insulator. In this step the only potential difference around the equivalent circuit is that which has been stored on the insulator layer. This charge on the insulator can now decay toward zero. In areas of the tape where the optical image is brightest the photoconductor resistance will be lowest and the potential decay will be most rapid. The potential decay for a light and a dark area of the optical image is shown in Fig. 3. At a time (t_{max} in Fig. 3) corresponding to the greatest difference between the potential in a light and in a dark area the electron flood beam is turned off and the discharging process stops. An electrostatic charge image corresponding to the optical image is now fixed on the insulator layer. The tape can now be rolled up and stored for the required length of time.

To convert the stored electrostatic charge pattern into a video signal for transmission to the ground, the tape is moved in front of an electron gun giving a finely focused beam. The original potential difference V is established around the circuit and the tape is scanned by the focused beam. Each individual elemental area of the tape, when contacted by the beam, charges from its stored potential back to the original potential V. The charge required to do this flows through

* "Cronar" is the registered trade mark for du Pont's polyester film base.

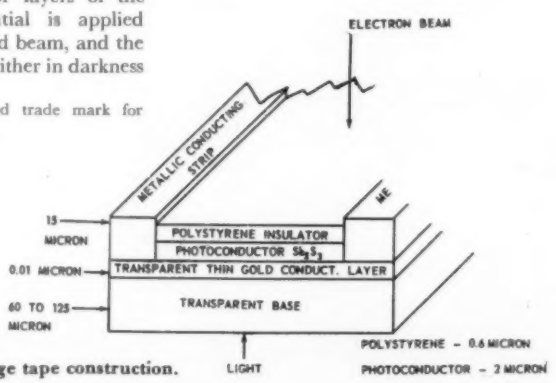


Fig. 1. Electrostatic storage tape construction.

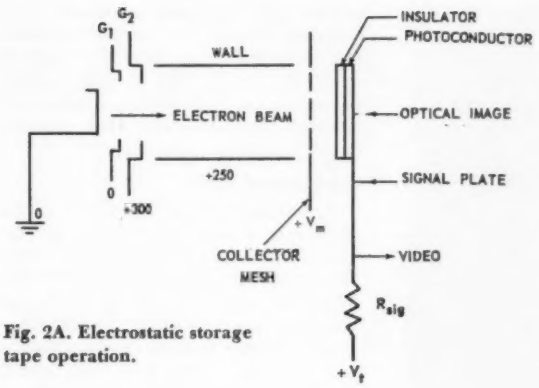


Fig. 2A. Electrostatic storage tape operation.

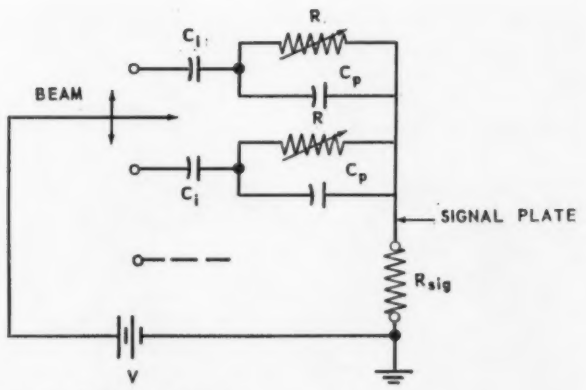


Fig. 2B. Equivalent circuit.

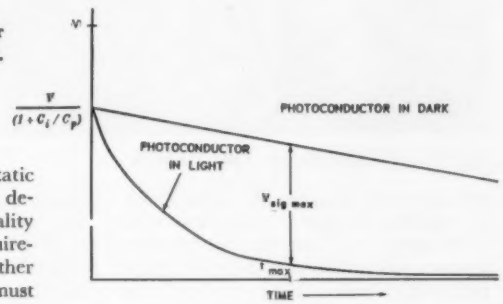
a signal resistor, R_{sig}; the voltage developed across this resistor constitutes the video signal, which can then be processed with conventional television equipment.

Design Considerations

The capacitance of the photoconductor layer has been ignored in this description because it plays a secondary role. The photoconductor capacitance bypasses the photoconductor resistance during readout, and is an aid in that respect. It is a detriment in the respect that, in accordance with theory of Rose and Lampert,[1] the maximum obtainable quantum gain of phototape using a simple photoconductor is $(1+C_i/C_p)$ where C_i and C_p are the insulator and photoconductor capacitances, respectively. Since C_i is fixed from practical considerations, it is desirable to have C_p low, certainly not larger than C_i.

The normal operation of phototape requires that an electron beam drive the insulator surface potential both positive and negative. This is accomplished by operating with beam electron energies sufficiently high so that each beam electron dislodges more than one secondary electron from the insulator surface (high velocity). The surface will be driven positive (net subtraction of electrons) if these secondary electrons are collected elsewhere; it will be driven negative (net addition of electrons) if these secondary electrons are returned to the insulator surface. Electron energies in the neighborhood of 250 v are suitable. The equilibrium potential of the insulator surface is thus equal to the potential of the secondary collector. The potential V referred to in the equivalent circuit is therefore equal to the collector mesh voltage minus the target voltage V_T. During the reading process the insulator surface is being driven positive, the secondaries are being collected on a collector electrode, and there is no degradation of picture quality due to secondary electron redistribution over the insulator surface. This freedom to read at high velocity, which is not shared with commercial broadcast television camera tubes, aids in obtaining a high-resolution reading beam.

Fig. 3. Insulator potential decay.



The time which an electrostatic charge image can be stored is determined by the insulating quality of the insulator layer. The requirements for this insulator are rather severe. The insulator layer must be about 0.6 μ thick to obtain a capacity match with the photoconductor, and it must withstand about 20 v to provide a reasonable field for the photoconductor. The field across the insulator is then about 300,000 v/cm. The storage time required is at least 90 min, and thus, the ohmic relaxation time of the insulator at this field must be long compared with 90 min, so that there is no picture degradation.

Experiments have been performed with a number of insulating materials in an attempt to find the best one for this purpose. Inorganic materials which could be evaporated to form thin films and which normally have high resistivity, such as MgF_2, CaF_2, etc., would not withstand the extremely high electric field. Organic materials such as some vinylites, polymethylmethacrylates, and silicone resins were much better, but still marginal. The best material so far tested, and by a very wide margin, is polystyrene. The shortest ohmic relaxation time measured on a pure polystyrene layer at a field of 10^6 v/cm was three months.

A photoconductor has been chosen as the light-sensitive element for several reasons: (1) A photoconductor permits forming the stored image directly from the optical input and directly on the storage medium. This gives a system with a maximum of simplicity and a minimum of limiting apertures. (2) The quantum efficiency of a photoconductor in the visible red is quite high — considerably higher than that of a photoemitter, for instance. Use of a photoconductor, therefore, results in high sensitivity. (3) The tape transport must have precision mechanical parts, which cannot tolerate the heat treatment normally given vacuum tubes. The vacuum obtained in a tape camera will, therefore, not be as pure as the vacuum in normal tubes. The photoconductor, being relatively inert chemically, is not affected by the quality of the vacuum.

The quantum efficiency of the photoconductor presently used is approximately 50%. The sensitivity of the electrostatic phototape, therefore, is quite comparable with the sensitivity of other aerial photographic systems. A peak highlight exposure of 0.01 ft-c/sec is adequate for photographing a standard EIA test pattern.

The halftone rendition of the phototape is equal to that obtained from vidicon television camera tubes. This is as would be expected, considering their similarity.

The resolution of the phototape can be influenced by three factors: light scattering in the photoconductor, photoelectron diffusion in the photoconductor, and fringing of the electrostatic field across the insulator. Since the photoconductor presently used is glassy, the light scattering is negligible. A mathematical analysis has been made of the effect of photoelectron diffusion and field fringing on resolution. It indicates that the photoelectron diffusion is negligible, and that the effect of fringing is such that the minimum resolvable dimension will be approximately equal to the thickness of the insulator. For normal tape this is 0.6 μ giving a limiting tape resolution of 15,-

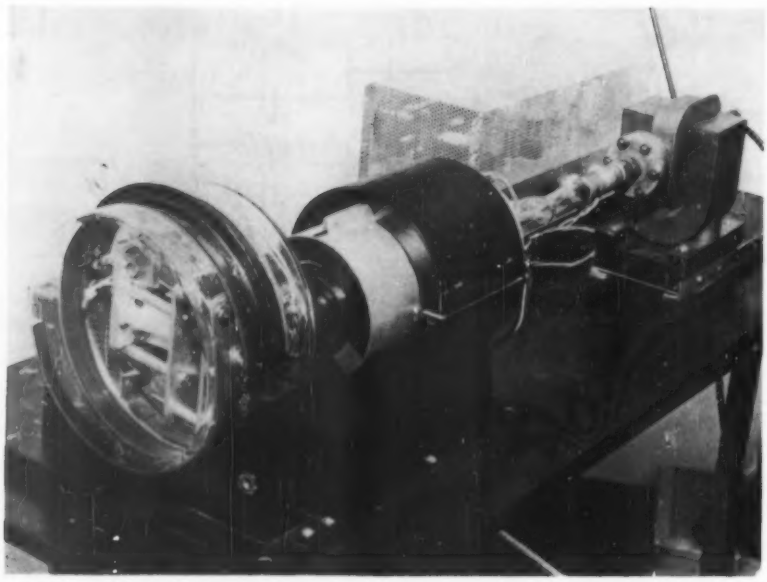


Fig. 4. Sealed Electrostatic Tape Camera.

000 television lines/cm. The calculated N_e of the tape is 3,300 television lines/cm.

Of course, the fact that the inherent tape resolution is so high does not mean that such resolution can be obtained from a tape camera at present. The difficulty is in obtaining an electron gun with a sufficiently small beam cross section to read this resolution from the tape. However, the ability of the tape to be read at high velocity considerably eases the problem of providing a high-resolution reading gun.

From the above discussion and the description of the phototape operation, it is evident that, with the exception of the optical system and the transmitter, which are common to any system, the resolution of an electrostatic imaging and recording camera system is essentially determined by only one limiting aperture — the reading electron beam.

Writing, storage and reading are accomplished with no tape processing beyond contact by an electron beam. As would be expected from this fact, the tape is almost indefinitely reusable. The end of its life comes when the rolling and unrolling process has caused mechanical wear of the Cronar base.

The phototape is not optically sensitive except while being contacted by an electron beam, and it is made of materials which are relatively insensitive to radiation. Davidson and Rosen[2] report that the antimony trisulfide photoconductor is relatively unaffected by radiation, and Monk[3] and Woodward[4] report that some types of polystyrene neither color nor show enough resistivity reduction to affect phototape operation even when exposed to high amounts of radiation. Two radiation tests have been made to date on the phototape. One was to determine if radiation would change the conductivity of the photoconductor, i.e. appear as light. The photoconductor was exposed to 250 R/hr of 1 mev x-rays. There was no change in conductivity. The second test was to determine if radiation would affect the stored image on phototape. A stored image was exposed to 100 R/hr of 1 mev x-rays for one hour. There was no discernible deterioration in the quality of the stored picture. It seems reasonable, therefore, to assume that a phototape camera would not be seriously affected by Van Allen radiation.

On one point a problem was expected, but it has not been found in tests so far made. Difficulties were expected from the effects of rolling an insulating tape with an electrostatic charge on a reel. Of course, there is the electrical contact strip along the tape edge, but there is no definite proof that the strip either does or does not separate the layers of tape. (It is not possible to make the contact strip nearly as thin as the photoconductor-insulator layers and have it retain sufficient mechanical strength; therefore, it has not so far been possible to see what happens when the contact strip thickness is negligible.) However, in testing a number of tapes many times in two different tape transports, no deterioration of picture quality has been observed.

There is a problem with the tape transport motors and ball bearings because of the requirements that they operate in a camera-tube-quality vacuum. However, the problem is mitigated by the fact that tape speeds are slow (because of the high information density of the tape) and consequently tape transport rotational speeds are low. There are several types of ball bearings which are suitable for use in vacuum. These include x-ray tube bearings, high temperature bearings, and bearings with solid lubricants. Motors of the type with solid armatures (and most synchronous motors can be made this way) are relatively easily adapted to use in vacuum. The winding is either potted in a nonvolatile material or hermetically sealed. The solid rotor requires no special attention.

Experimental Work

A number of experimental devices employing electrostatic image storage have been made. These include: fixed phototape targets sealed in 6198 vidicon envelopes, fixed phototape targets sealed in camera tubes with electron multipliers, a demountable vacuum system with a tape transport, and a completely sealed phototape camera. The phototape targets in vidicon envelopes and the demountable tape transport have been constructed primarily for research. The phototape targets in tubes with electron multipliers will be evaluated for use in extremely low bandwidth systems as would be used for lunar or interplanetary probes.

An experimental sealed phototape camera is shown in Fig. 4. It consists of a short length of phototape and a bi-directional stepping motor with gear train to move the tape between two reels. Reading and writing are done with an image-orthicon electron gun. The camera is maintained at operating vacuum by a Varian Vac Ion pump. Undeteriorated pictures have been read from this camera after having been stored rolled on its reels for periods up to two weeks.

Conclusions

All of the basic operational features of an electrostatic imaging and recording system using television phototape have been incorporated in a number of laboratory models, and the system has been shown to represent a marked advance in the possible methods of recording, storing and transmitting pictorial information from satellites. Particularly important features are: a minimum number of limiting apertures, the easy erasability and reuse of a true image storage medium (as contrasted to signal storage, for example), and the relative insensitivity to radiation effects. No basic difficulties appear to exist in the development and design of a ruggedized camera capable of actually being flown in a satellite.

References

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2. A. R. Davidson and B. H. Rosen, "Effects of radiation on vidicon performance," *IRE Trans. on Nuclear Science,* NS-5: 46–49, Aug. 1958.
3. G. S. Monk, "The coloration of optical materials by high energy radiations," Argonne National Laboratory, ANL-4536: 25.
4. R. E. Woodward, "Electrical properties of irradiated polymers," WADC TR 56-465, June 1957.

Discussion

Anon: Is the readout of the stored information destructive?

Dr. Hutter: The way we usually run it, in our present method of readout, it is partially destructive. The greater part of it is gone in the first readout, but a recognizable picture can be produced for the next two or three readouts. We want to erase it after one readout for all satellite uses; it was not designed to be a permanent storage.

Anon: Would not the high capacitance to ground of the signal plate in the tape limit the range of light levels?

Dr. Hutter: I don't see why the capacity of the signal plate would necessarily limit the light levels. The capacity of the signal plate has a bearing on the speed at which you can read it out, but there are ways to get around that, such things as using return beam readout, for instance, where the signal plate is merely a source of d-c bias. Once the image is on there you can read it out at a perfectly normal video rate.

Anon: Does the readout have to be done with a low-velocity beam?

Dr. Hutter: No, it can be done with a high-velocity beam; that has been done.

B. R. Linden (CBS Labs.): Do the high-velocity electrons induce any physical changes in the polystyrene?

Dr. Hutter: No, they do not. We have made quite a number of measurements on the basic method of charge storage in the polystyrene. We are going to issue some reports on this, but, the gist of them is that they do not seem to induce any bombardment conductivity at the voltages we are using (approximately 250-v electrons) or penetrate the polystyrene.

Anon: Would you comment on the lifetime you would expect from the bearings in the camera as they were operated in vacuum?

Dr. Hutter: In this particular model that you saw, we were not really interested in trying to give the bearings a life test, but rather in trying to put together all the necessary parts for a camera. In this one we took standard ball bearings and very gently removed all the grease, got them cleaned, heated, and baked, etc., before being put together. A vacuum problem in this camera arose from the Synchromental motor which drives the tape. This was originally wound with some plastic insulated wire and we had to re-wind it with glass-fiber insulated wire. We have looked ahead into the bearing question and have been and still are making quite a number of tests on bearings. The results to date are quite encouraging. There are a number of these such as the Machlett silver-coated bearings that are used in x-ray tubes. We have run these for hundreds of hours in high vacuum. We have also used special, hardened bearings which we have obtained from New Departure for this purpose. These are precision bearings in the sense that the Machlett bearings are not, and ultimately, in TV reconnaissance precision will be of importance. We have run them — I don't remember the exact figure but it is somewhere between 500 and 1000 hours — at a pressure of about 10^{8} mm of mercury and they held up very well.

We are also making tests on several other types of bearings, and it looks as though Molykote bearings will work. (Note: subsequent tests have shown that in an oil-free high vacuum these bearings are not satisfactory.)

M. Tragers (Massachusetts Institute of Technology): Do you have any out-gassing from the polystyrene?

Dr. Hutter: The polystyrene, strangely enough, seems to be one of the, you might say, minor problems. When we first started making these tubes, the vacuum technology people spoke with horror of having something like polystyrene in a tube. Actually we have tested several of the single target tubes, such as the group of four I showed on one of the slides, which have polystyrene coated targets. These have been sealed up and we have kept some over a year. They were still functioning.

Mr. Sojay (Convair Astronautics): Do you see any possibility of arranging tape storage of this sort of image over a period of a year or more?

Dr. Hutter: I would say there's certainly a possibility that you could actually store a picture for over a year or more. I wouldn't say that we could do it — we haven't done it; we haven't tried to do it. The basic limitation is how good the polystyrene is. We think the conditions for surface leakage are very good (i.e., low surface leakage) because the electron beam inherently tends to clean up the surfaces bombarded, and it's in a perfectly dry, vacuum atmosphere. If you take the bulk resistivity of polystyrene as that which we get in thin samples, as being in the order of 10^{17} ohm centimeters or thereabouts, and if you compute the *R-C* time constants on this basis, the time constant is in the order of 3 to 6 months. It varies somewhat with the thickness of the specimens. I would guess that at the end of the year it would certainly have gone down. I would think there would probably be something which you could still recover.

Mr. Sojay: Did you mention anything about the gray scale obtained with this?

Dr. Hutter: We have obtained the normal, approximately 8-10, gray scales as seen in a standard EMA test pattern. We usually check these tubes by looking at this pattern.

Satellite Astronomical Telescopes

By NANCY G. ROMAN

The program of the National Aeronautics and Space Administration includes several projects designed to obtain astronomical observations from satellites. Telescopes with apertures up to at least 36 in. appear to be practical for satellite use. They will be individually designed for particular spectral regions and particular experimental objectives and usually will be based on photodetectors and electronics imaging devices which will substitute for the camera and the human eye.

THE EARTH'S ATMOSPHERE, so vital to the development and sustaining of life, is a severe hindrance to the accumulation of astronomical observations from the surface of the Earth. This atmosphere has two major effects. First, it is opaque or only semitranslucent to most regions of the electromagnetic spectrum. Second, the radiation which does penetrate the atmosphere to the surface of the Earth is distorted by scattering and by the variable indices of refraction encountered in small patches in the atmosphere.

Except for average stars such as the Sun, no astronomical body has its maximum blackbody-emission in the visual atmospheric window, and none has its blackbody-emission maximum in the radio region of the spectrum. In spite of this, many important astronomical emissions are in or near the visible region of the spectrum (Fig. 1). It remains to be determined from observations beyond the absorbing screen of the atmosphere whether this indicates a true physical concentration, or merely a concentration of those objects about which we have been able to acquire information from the surface of the Earth. Four projects among those in the Observational Astronomy and Solar Physics programs of the National Aeronautics and Space Administration (see Table I) are designed to obtain such astronomical observations. A Gamma Ray Astronomy Project will measure the spatial and frequency distribution of very high energy photons; an Orbiting Solar Observatory Project and an Orbiting Astronomical Observatories Project will explore the region of the spectrum in which optical techniques can be employed; and an orbiting Radio Astronomy project will provide observations of the long-wave end of the spectrum.

Although astronomers tend to use the term "telescope" to refer to any instrument used for studying photons from celestial sources, the Merriam-Webster Dictionary defines a telescope as "an optical instrument used as an assistance to the eye or camera in viewing, or photographing, distant objects. . . ." In keeping with this definition, this paper deals only with that region of the spectrum in which optical techniques are applicable — that is, from perhaps 100 A to about 1 mm. The possibility of observing radiation from nearly six decades of the electromagnetic spectrum clearly, instead of radiation from only about one decade hazily, is an exciting one to astronomers and has aroused widespread interest in the Orbiting Astronomical Observatories Project.

Stabilized Platform System

In this project, the plan is to launch several satellites specifically designed for astronomical observations (Fig. 2). The optical instrumentation will differ from one launching to another according to the experiment or experiments being conducted, but the remainder of the satellite will be nearly identical for each.

Presented on October 6, 1959, at the Society's Convention in New York by Nancy G. Roman, Observational Astronomy Program, National Aeronautics and Space Administration, 1520 H St. N.W., Washington 25, D.C.
(This paper was received on October 20, 1959.)

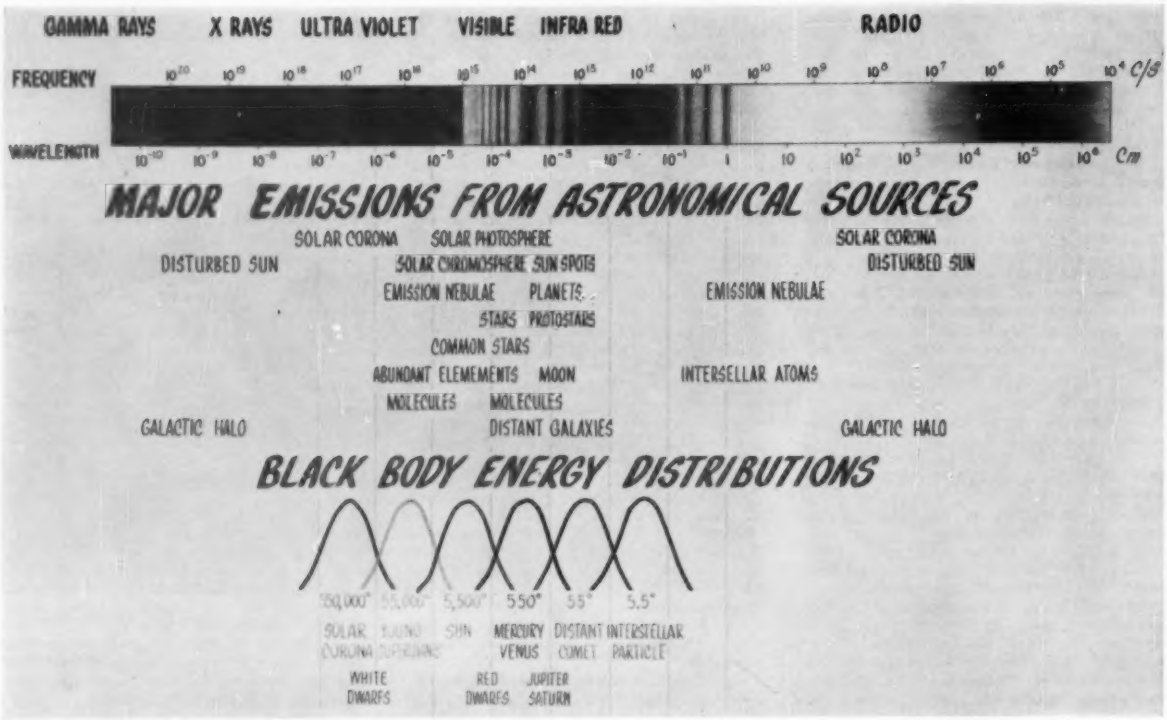

Fig. 1. Atmospheric transmission in relation to major emissions from astronomical sources and blackbody energy distributions.

For simplicity we are calling this common package the stabilized platform system, although it will bear no resemblance to a platform and will contain much more than the stabilization mechanism. However, stabilization will be important since the great distance of astronomical objects makes most of them appear very small and faint. To observe them, a telescope must be pointed at an object accurately and held there for a long time. The stabilization system for this project will be designed to permit pointing within a second of arc, or better, for periods of up to an hour in length.

In addition, the "platform" will contain telemetry equipment, power supplies and some type of starfield acquisition system. The latter may be a small telescope similar to a finder on a terrestrial telescope, which will form an image of the sky on a television screen for transmission to Earth. The astronomer at the terrestrial control center can then know exactly where in the sky the instrument is pointing, and can move it to a particular star by means of commands from the ground. Presumably, some type of coding of the TV signal would be used to save bandwidth and, consequently, power. Certainly the scan rate would be about one per second rather than the normal 30 scans/sec used in commercial television. In addition to the bandwidth, the sensitivity and the dynamic range required for such a television system may be serious problems.

Table I. Projects of National Aeronautics and Space Administration.

Observational Astronomy Program

Orbiting Astronomical Observatories Project: photometry and mapping; spectroscopy
Gamma-Ray Astronomy Project: sky survey; advanced experiments
Orbiting Radio Astronomy Project: low frequency; high frequency
Relativity Investigations Project: gravitational clock; gravity monitor; artificial planet
Advanced Galactic Investigations Project: orbiting optical observatory; optical instruments on Moon; lunar astronomical observatory; orbiting radio observatory; radio astronomy instruments on Moon; lunar radio astronomy observatory

Solar Physics Program

Orbiting Solar Observatory Project: disc survey; centers of solar activity
Solar Radiation Rockets Project: selected regions; x-ray spectra; ultraviolet spectra
Solar Probes Project: solar corona; chromosphere and photosphere; solar terrestrial relationships
Advanced Solar Observations Project: terrestrial orbiters; planetary orbiters; artificial planets; lunar observatory

To be useful the acquisition system must detect clearly stars of at least 6.5 magnitude; that is, slightly fainter than the faintest stars that can be seen by naked eye on a dark, clear night, or in energy units, less than 10^{-8} ergs/sq cm/sec. At the same time, the tube must be able to accept light from stars almost 400 times as bright without serious fatiguing, and without affecting the performance of the remaining area of the tube. Moreover, contrast discrimination must be sufficient to permit the distinguishing of at least eight light levels approximately equally spaced in logarithmic intensity within this range. Such a system is near the limit of the present state of the art, but it does not seem to be beyond it.

Princeton University plans to use a TV finder system, similar to that described above, for pointing a 36-in. balloon-borne telescope as part of Project Stratoscope. A TV finder system for solar photography has already been flown and found successful both for guiding and for focusing. Some of the experiments, such as mapping the sky in the far ultraviolet or in the infrared, will also use electronic devices for image detection and transmission. These devices will entail higher sensitivity, greater dynamic range and appreciably greater contrast discrimination than is required for the starfield acquisition system and will involve advances beyond the present state of the art.

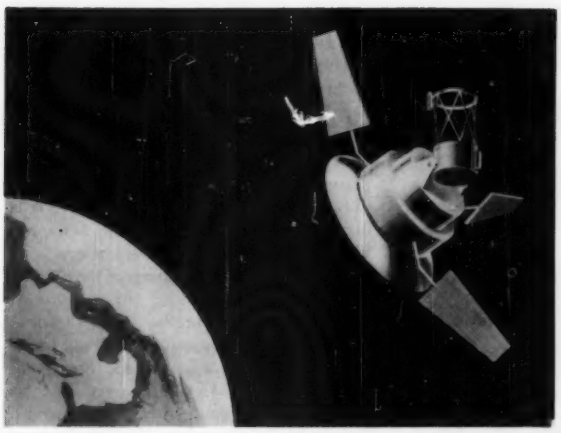

Fig. 2. Artist's conception of a satellite telescope.

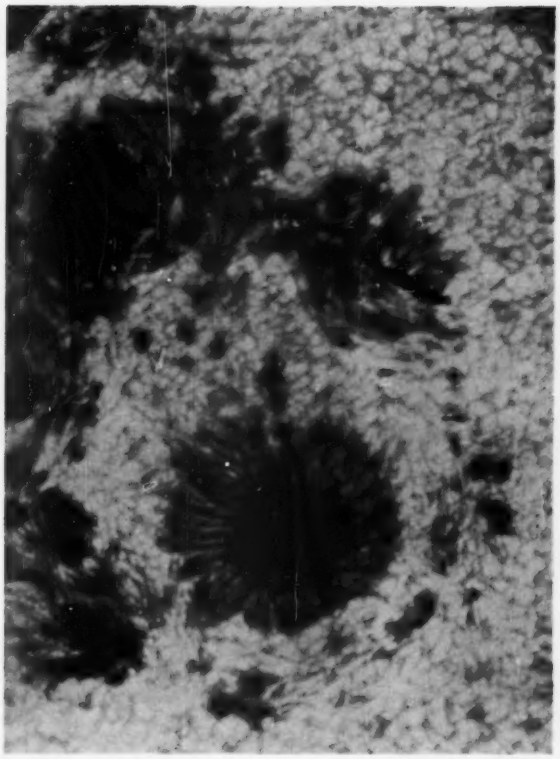

Fig. 3. Photograph of sunspot taken from a balloon with a 12-in. telescope by Princeton University Observatory. (Project Stratoscope of Princeton University, sponsored jointly by the Office of Naval Research and the National Science Foundation.)

Photomultipliers and Photoconductive Cells

In the past, the astronomer has been dependent on photographic emulsions for recording observations of celestial phenomena. In recent years, there has been a greater tendency to use photomultipliers and, in the infrared, photoconductive cells for measuring brightnesses of stars and for spectrophotometry; that is the determination in detail of the brightness of a star as a function of wavelength. Because astronomy itself has been restricted to that wavelength range, photomultipliers and photoconductive cells have been used only between about 3000 A and 5 μ. We shall now need photosensitive surfaces in other spectral regions, particularly the far ultraviolet. The photoconductive cells which have been used in the infrared are too insensitive to compete with the photographic plate in regions where both are usable. For the full effectiveness of satellite astronomy, the sensitivity of infrared detectors must be appreciably increased.

Electronic-Imaging Devices

Astronomers have looked longingly at the high quantum efficiencies of photoelectric surfaces with their yields near 20% of the theoretical maximum as compared with a small fraction of 1% for photographic plates, and have worked on the development of electronic-imaging devices suitable for astronomical observations. So far, the lack of satisfactory storage capability has prevented the use of purely electronic imaging techniques; the most satisfactory results have been obtained from the use of electronic image intensifiers in conjunction with photographic plates. Good resolution has also been difficult to obtain because of the spread in velocity with which electrons leave the cathode.

In the satellite we shall not depend on the use of photographic plates. Thus, we are faced with two developments beyond the present state of the art, the development of photosurfaces and, of course, of photomultipliers, for use in the newly opened regions of the electromagnetic spectrum and the development of electronic image tubes which will provide extreme sensitivity, good resolution and large dynamic range, and, at the same time, fine contrast gradations.

Sunspots and Solar Flares

There are various problems which we hope to solve with our space telescopes. For example, when the Sun (an approximately spherical mass of gas like all stars) is viewed visually, or photographed in the light of a large wavelength region, it presents a sharply defined edge and a comparatively smooth disc marred only by small dark regions called sunspots. These regions are much cooler than the surrounding area of the Sun, and also exhibit strong magnetic fields. Viewed under excellent conditions with a large telescope, the surface of the Sun appears mottled by "granulations" and the regions near the sunspots show some striation. Photographs obtained with a 12-in. telescope from a balloon in the Princeton Project Stratoscope are better than it has been possible to secure on the surface of the Earth, even with much larger telescopes. The granulations are clearly visible, and the markings around the sunspots are strikingly obvious (Fig. 3). From a satellite we might gain even greater resolution on the Sun, but more importantly we would have comparable resolution for observing planets, crowded starfields, close binaries and distant galaxies. For the latter objects, comparable results cannot be obtained from a balloon because long integration times will be necessary to reach faint limiting magnitudes.

Associated with the sunspots are other evidences of disturbances in the solar atmosphere, such as solar flares. These flares emit intensely in the light of the hydrogen lines, in the far ultraviolet, in the radio region of the spectrum and possibly in the x-ray region. In addition, there is evidence from studies of auroras and geomagnetic fields that the flares also, at least at times, produce particles which travel toward the Earth and disturb its upper atmosphere. From a satellite we shall be able to study the ultraviolet and infrared emission from the flare and the relationships between the emitted energy at various wavelengths. The normal solar spectrum in the far ultraviolet will not only provide information on the upper atmosphere of the Sun but will also permit the identification of elements whose presence in the Sun can now only be suspected.

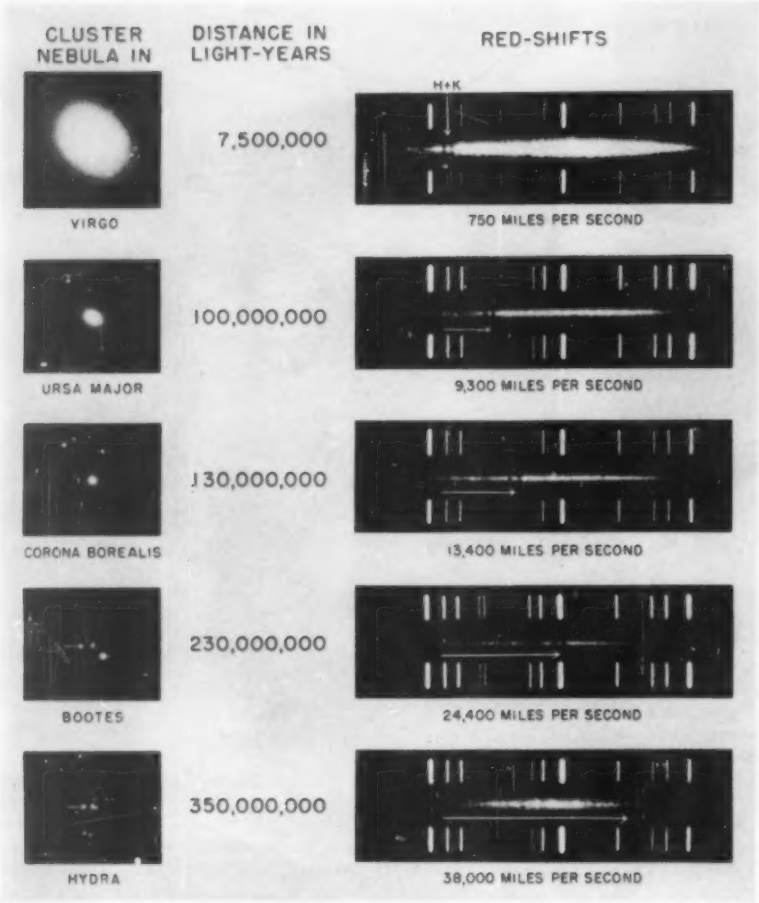

Fig. 4. Relation between red-shift and distance for extragalactic nebulae. Red-shifts are expressed as velocities, $cd\lambda/\lambda$. Arrows indicate shift for calcium lines H and K. One light-year equals about 6 trillion miles, or 6×10^{12} miles. (Courtesy Mount Wilson and Palomar Observatories.)

Planets and Stars

The planets will also be important objects to observe from space telescopes. The greater resolution will permit us to see much finer details, and, for example, may determine the nature of the canals on Mars. Also, from infrared observations we shall learn much about the surfaces and atmospheres of the planets.

Not all stars are of the same temperature as the Sun. Many are much hotter, others much cooler. Only a small portion of the radiation from such stars can be observed in the visual region of the spectrum. Although astronomers are unwilling to predict what surprises may be in store for us when such observations are possible, they know that they will learn appreciably more about the structure of the atmospheres when all the radiation of these stars can be studied. Two types of stars will be particularly interesting, the so-called T Tauri stars and the flare stars. T Tauri stars appear to be young objects which have not yet fully developed into normal stars. They are characterized by extreme variability of light and by ultraviolet emission lines. The flare stars suddenly brighten by many orders of magnitude, and then fade again almost immediately, returning to their original state in periods of a few minutes, an amazingly short time for an object as large as a star. Both types of stars appear to emit intensely in the ultraviolet; the phenomena may resemble that of solar flares.

Interstellar Space and Galaxies

Although interstellar space is far less dense than the best vacuum that can be obtained in a terrestrial laboratory, it is far from empty. Between the stars are both gas atoms, primarily hydrogen, and dust grains. The prominent hydrogen spectral lines are in the radio region of the spectrum and in the far ultraviolet. The presence of emission from the latter can only be surmised from terrestrial observations, but would certainly be readily visible from a space telescope. The dust grains, in spite of their extreme tenuity, occur in such large volumes that they are effective in blotting out the light of the stars behind them.

Observation from a space telescope in the infrared will, for the first time, permit us to observe the center of our galaxy and other interesting regions. Moreover, in the far infrared, the dust grains will also emit radiation and we should be able to learn more about their nature by studying their spectra in this region.

Space telescopes will also contribute to answers to two important cosmological questions: Are planets observable around other stars, and are distant galaxies identical to our own or do they show effects of time and distance? If there is a solar system such as ours around any of several of the nearest stars, it could be observed from a space telescope provided the telescope could maintain extremely accurate pointing for long periods of time. Presumably our natural satellite, the Moon, will provide the best base of operations from which to look for such planets. The well-known red-shift, which shifts the spectrum of distant galaxies to the red by an amount proportional to the distance (Fig. 4), means that for very distant objects we can observe from the surface of the Earth only those regions of the spectrum which are unobservable in nearby galaxies. Space telescopes, with which observations can be made over large wavelength ranges, will enable us to compare accurately the spectra of nearby and distant galaxies and determine if there are evolutionary differences between the two. Finally, the greater resolution of space telescopes will permit us to observe galaxies at distances several times that which can be reached from a 200-in. telescope and thus may, at last, give us a glimpse of the edge of the universe.

Television and Lunar Exploration

By S. W. SPAULDING

Television techniques are planned to aid in the exploration of the lunar surface, with emphasis on the obtaining of high-resolution pictures from an impacting probe. A television link back to Earth will permit controlled soft-landings on the Moon and subsequent surface examinations. The optics, the television and the communications parameters are considered.

THE MOON has long been an object of scientific study. Recent technological advances, bringing closer the day of manned landings on the Moon, have served to heighten interest in it. The same technology has provided new means of studying the lunar surface and of giving answers to issues raised in past studies.

Earth-based telescopes have been used in conjunction with spectroscopic analyses and other photographic techniques to provide a background of data on the lunar surface. In this way estimates of the surface characteristics have been made. The temperatures, the thickness of the surface dust and many geological features are fairly well understood. Other features, such as lunar outgassing, crater origin and radioactivity, are still the subjects of conflicting theories.

A rocket-launched payload which would carry a television camera system close enough to the Moon to obtain some high-resolution pictures would add some very useful data which might resolve some of the issues in question. The same payload instrumented with additional sensors can determine the temperature, magnetic field and radiation field.

Later, landed vehicles will have the capability of some physical analysis of the lunar surface materials. Television will provide close viewing of the surface from such landed probes.

This paper describes some of the principal television parameters for systems to be used in circumlunar probes, impacting probes and soft-landed probes.

System Parameters

Trajectory Data. The overall geometry of an Earth-Moon trajectory is illustrated in Fig. 1. Such a trajectory could be used for an impacting probe or a soft-landed probe, and with slight changes it would serve as a circumlunar trajectory for a payload to pass close around the Moon and return to the vicinity of the Earth.

The Earth rotates during the flight of the payload, and the exact period of data transmission varies with the mission and the trajectory actually achieved. A number of ground stations are required to provide coverage and assure complete reception. Such stations are already planned or built.

For an impacting probe the part of the trajectory in the neighborhood of the Moon is the most important part for determining the number and type of pictures obtained. Figure 2 shows the time history of altitude and velocity for some trajectories starting with zero initial velocity at various initial altitudes designated by h_0. Thus a rocket payload whose vertical velocity is brought to zero at an altitude of 500 miles above the lunar surface would have a free-fall time to the surface of some 1500 sec. This time could be used for picture taking and transmission. The time spent on this same trajectory below an altitude of 100 miles is about 150 sec. Figure 3 shows that approximately one-fifth as much total time is available for picture taking below a 500-mile altitude if no retrorocket is used.

Resolution. The resolution available in pictures of the Moon taken from the Earth's surface is limited by the effects of the Earth's atmosphere to about 2500 ft. At this level of detail only the gross features are discernible. Details important to manned landing cannot be resolved from the Earth's surface.

Figure 4 illustrates the range of resolution attainable at different altitudes with an optical system designed for use with a vidicon camera tube in a space-vehicle environment. A resolution better than 50 ft is attainable with an impacting probe. With this detail available in a picture, many more features will be discernible, and it is hoped that the question of lunar crater origin can be settled.

For a circumlunar probe which might approach as close as 1000 miles altitude from the Moon, the resolution will be better than 1000 ft. Thus pictures of the Moon's normally out-of-view face would be available at a resolution better than pictures from an astronomical telescope on the Earth's surface.

The soft-landed probe would use its television at still better resolution since the close-up view would show complete detail. The television system would be an important part of the control system during landing and during surface exploration, where good resolution is mandatory.

Communications. The time required to send one television picture from the Moon to the Earth is a function of the available transmitter power and the number of television lines per picture. For a 500-line picture and 600-w transmitter power, 1 min is required per picture. A 200-line picture would require about 10 sec with the same transmitter power. This assumes crossed dipole antennas on the probe and a 60-ft diameter receiving antenna on the Earth. Later probes will take advantage of the power and time savings possible with the use of high-gain stabilized antennas on the probe. However, this paper assumes no such antenna gain.

Other communication channels are needed for tracking, command control and telemetry. A beacon at 960 mc serves for telemetry and tracking. An available receiver would serve for the command function to control the probe during the various phases of its operation.

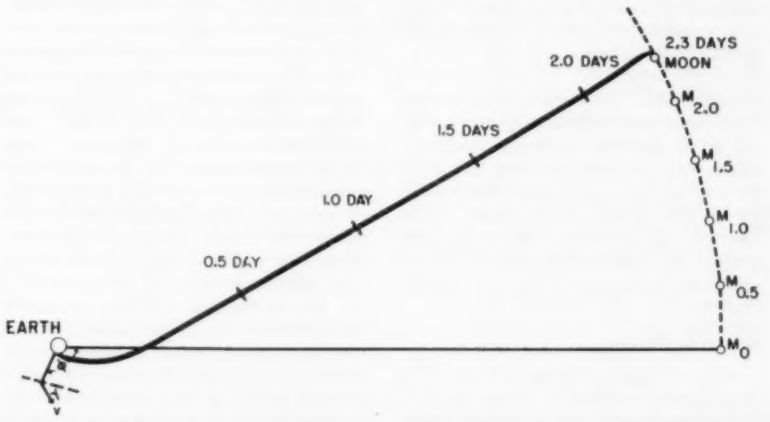

Fig. 1. Earth to Moon impact trajectory. Legend: r = 4300 mi; $\phi = -108°$; v = 35,000 ft/sec; $\gamma = 14.2°$.

Presented on October 6, 1959, at the Society's Convention in New York by S. W. Spaulding, Astro-Electronic Products Div., Radio Corp. of America, Princeton, N.J.
(This paper was received on September 4, 1959.)

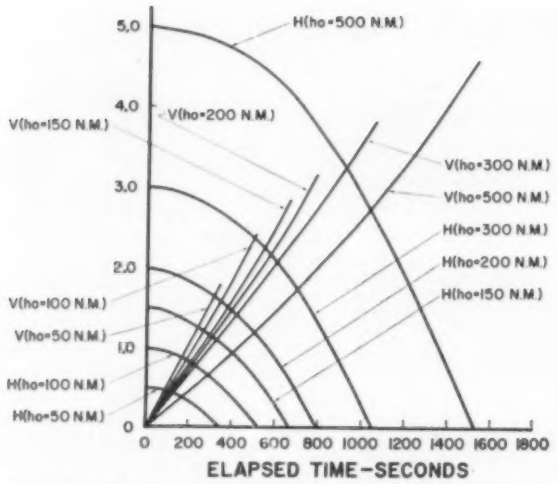

Fig. 2. Free-fall trajectories in the vicinity of the Moon. N.M., nautical miles; h_0, initial altitude; velocity (V), $\times 10^3$ ft/sec; height (H), $\times 10^3$ nautical miles.

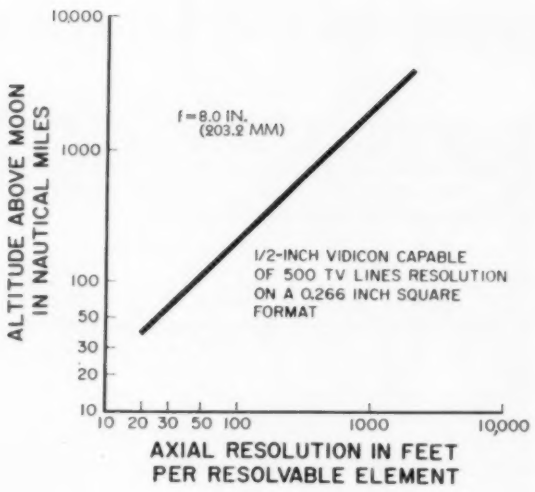

Fig. 4.

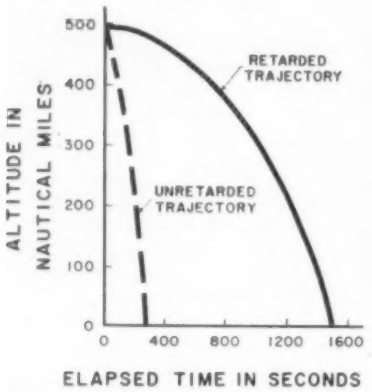

Fig. 3. Altitude-time history.

Power Supply. The power supply for a lunar probe can be a combination of solar cells and batteries or only batteries. For long-term modest power drain, the solar-cell, rechargeable battery combination is preferred. For a short-term, high-power drain, a nonchargeable battery is available with a capability of 40 whr/lb of cells.

Stabilization. The earliest lunar probes have been spin-stabilized. Later probes are to be stabilized and capable of attaining an orientation along the local vertical of the lunar surface under the probe. This feature is important to the concept of the retrorocket retarded probe, the soft-landed probe, and is convenient in designing the camera system.

Impacting Probe

With the above factors in mind it is now possible to discuss the results of a design study for an impacting lunar probe intended to give better than 50-ft resolution on at least one 500-line picture. Such a picture would cover about a 5-mile square on the surface of the Moon. The highlights of this design are now discussed.

Payload. The payload would consist primarily of an attitude-stabilized package containing a television transmitter. In addition, there would be a command receiver with associated control circuits for programming the system, and a beacon to supply tracking signals as well as the desired telemetry. The vehicle would be properly directed and attitude stabilized during its approach to the Moon. A lunar horizon scanner would be used to provide altitude information. In a different configuration it would also provide information for vehicle stabilization. During the approach period, beginning at an altitude of approximately 5000 nautical miles, a few distant pictures would be taken on command from the Earth to furnish orientation information.

The altitude information from the horizon scanner would be automatically sampled and transmitted by the television transmitter during the short period when the video information is not transmitted. This would give altitude coding information for each picture. Before regular picture taking is programed, altitude information would be sampled on command. At the desired altitude, the retrorocket would be fired. Further pictures would not be taken until after burnout, after which a sequence of pictures one minute apart would be taken. After storage in the tape recorder, playback would be slowed approximately 30-to-1 to effect similar reduction of bandwidth and required transmitter power. Residual images would be ready for a new exposure when the one-minute playback is completed. A shutter would be used for smear minimization. With a vidicon sensitivity of 0.5 ft-c-sec, pictures with excellent signal-to-noise ratio should be obtained with the available lunar illumination. Since the Moon's reflectivity may vary considerably depending upon the particular target area, a light sensor would provide the necessary information for altering the vidicon sensitivity by a factor of two in order to ensure, at all times, that the dynamic range of the vidicon would not be exceeded.

Television Camera. A block diagram of the camera system is shown in Fig. 5. The picture-taking function would be performed by a $\frac{1}{2}$-in. vidicon. Magnetic deflection coils would be driven by transistor amplifiers stabilized for temperature changes and designed to withstand rocket launching and space environment. Other circuitry would include a focus current regulator for maintaining constant current in the focusing coil; a dc-dc converter to provide vidicon operating voltages; a blanking amplifier for eliminating the electron beam during deflection retrace time; a shutter control circuit for actuating the shutter at a programed interval, or upon command from the Earth; and a focus-control circuit which would be designed to correct errors in optical focus. The video signals from the vidicon would be amplified by a preamplifier mounted on the vidicon yoke, which in turn would feed a transistorized video amplifier. This amplifier would include a circuit for restoring the d-c component followed by a d-c video amplifier for driving the tape-recorder modulator. These transistor circuits also would be stabilized and ruggedized.

The vidicon raster would consist of 500 scanning lines on a square format, 0.25 in. on a side. By making the line rate 250 cps and the frame time 2 sec, the required video bandwidth into the tape recorder would be 62.5 kc. A 30-to-1 reduction in

playback speed of the recorder would then result in a required transmission bandwidth of approximately 2 kc.

The weight of this camera would be approximately 6 lb, and the power consumption would be less than 10 w. The circuitry and packaging could be very similar to that built for other space vehicles. Only a few design changes would be necessary to fit it into any short-term program.

Optics. The optical requirements are rather severe since a picture of high ground resolution must be obtained at a relatively high altitude, which specifies a focal length of 8 in. or more. To ensure adequate vidicon illumination (if the camera happens to be directed at a dark area of the Moon) a relatively low T-number must be specified, which means that the lens will have a diameter near that of its focal length. This indicates a rather large lens, which must, in addition, be ruggedized. The lens proposed is one for which the design has been completed and a model already constructed. This lens has a T-number of 1.35 and a focal length of 8 in., and is of the catadioptric type which combines reflective and refractive optical elements. It is designed to be mounted with a vidicon and includes a focus motor for making incremental focusing adjustments.

An average highlight brightness from the Moon of 1100 to 1200 ft-L is to be expected, but if a darker area is approached, the highlight brightness might drop to a range of 300 to 500 ft-L. A scene brightness sensor will be provided which would furnish telemetering information to Earth. For the conditions of maximum light, the vidicon sensitivity would be reduced by approximately 2-to-1, by reducing the target electrode voltage. This would ensure that the scene brightness range would vary through the more linear portion of the transfer characteristic. When a sequence of previous pictures had been taken, the scene brightness information would also be provided in this manner.

The sensitivity of the vidicons which will be used is 0.05 ft-c-sec for the highlights (upper portion of the transfer characteristic). A shutter will be provided for image immobilization. This lens, whose effective aperture ratio T is 1.35, will provide a faceplate illumination of 41.2 ft-L with a highlight brightness of 300 ft-L. The shutter opening time will be 0.0012 sec. If a longer exposure should be permissible, such as 10 msec, the size of the lens could be reduced, or its focal length increased. Increasing the focal length would permit the taking of pictures with increased ground resolution. However, for a 10-msec exposure time, pitch and yaw correction to the stabilized platform could not exceed 2 or 3 milliradians/sec (75 to 125 milliradians/sec along the roll axis). At the same time, assurance that the velocity vector would be along the nadir must be made. For a permissible smear of one-half of a television line, the lateral component of velocity should not exceed 1000 ft/sec; with a shutter speed of 1 msec, it could be 10,000 ft/sec. This is based on the altitude for the final picture of 50 nautical miles. For purposes of preliminary analysis it is assumed that the lateral component of velocity will be less than 5000 ft/sec. A shutter speed of approximately 2 msec is proposed. This gives some factor of safety in the exposure figures.

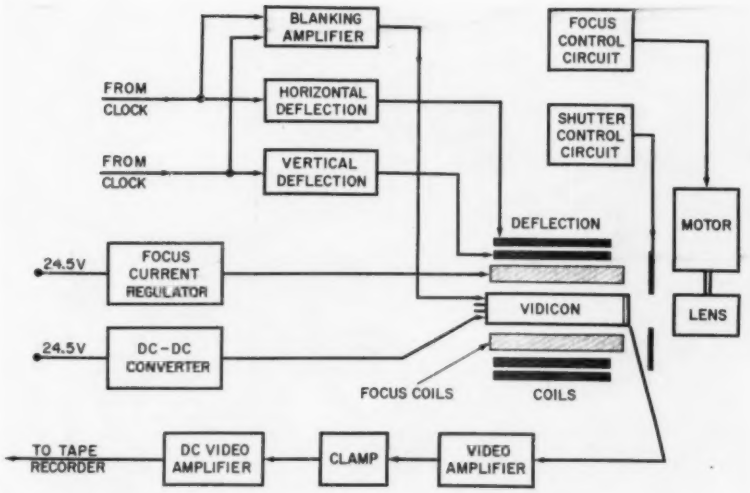

Fig. 5. The camera system.

Tape Recorder. The tape recorder (Figure 6) will be a modification of a present design being used in a satellite project. A dual-speed motor will be provided to produce a tape speed of 60 in./sec for recording and 2 in./sec for readout. The electronic circuitry will be transistorized and will consist of an FM modulator, using a carrier frequency of 85 kc, and the usual transistorized signal amplifiers. Control of the fast-record, slow-readout recorder can be vested in the recorder itself. It will use a simple position code on the ends of the tape to enable the machine to recognize that it has reached the end of the tape, and to identify the end which has been reached. The same sensing mechanism could be used to program the camera-recorder-transmitter system. A control signal from the command receiver or clock would start the camera and recorder in the recording cycle. When the tape reached its end, the camera video would be switched off and the transmitter turned on. At the same time, the recorder would be reversed and operated at the lower speed. When the other tape extreme was reached, the transmitter input would be switched to the altitude sensor, and the camera shutter operated, after which the recorder would again repeat its record cycle. This sequence would continue until impact or until commanded to stop.

The total weight of the recorder and circuitry, including the cover, would be 12.5 lb. Power consumption would be approximately 25 w.

Television Transmitter. The transmitter system would consist of a commercially available transmitter-exciter unit weighing about 1 lb followed by an intermediate power amplifier, also commercially available, which weighs 1.5 lb. The frequency will be in the 240-mc region. In order to deliver a signal to the Earth with a 2-kc bandwidth, transmitter power into crossed dipoles must be approximately 600 w. A 60-ft dish will be used on the Earth. A 600-w power amplifier of this nature is not commercially available but can be readily designed. It would use two Type-4CX300 tubes which would necessarily have special cooling means to operate in the space environment. A heat sink consisting of about 7 lb of water will be used. Water has a high specific heat and offers a medium for rapidly removing heat from the highly concentrated hot area. This heat sink will be placed inboard to maintain the temperature above freezing during the nonoperating part of the space flight. The temperature rise would be from 62 F to 212 F. The transmitter will require a dc-dc converter. The total input power would be about 1500 w.

Command Receiver. The command receiver would be of a type currently available for space vehicles.

Beacon and Telemetry Transmitter. In order to obtain the required gain from the 60-ft dish, a high-frequency transmitter in the 960-mc band will be used.

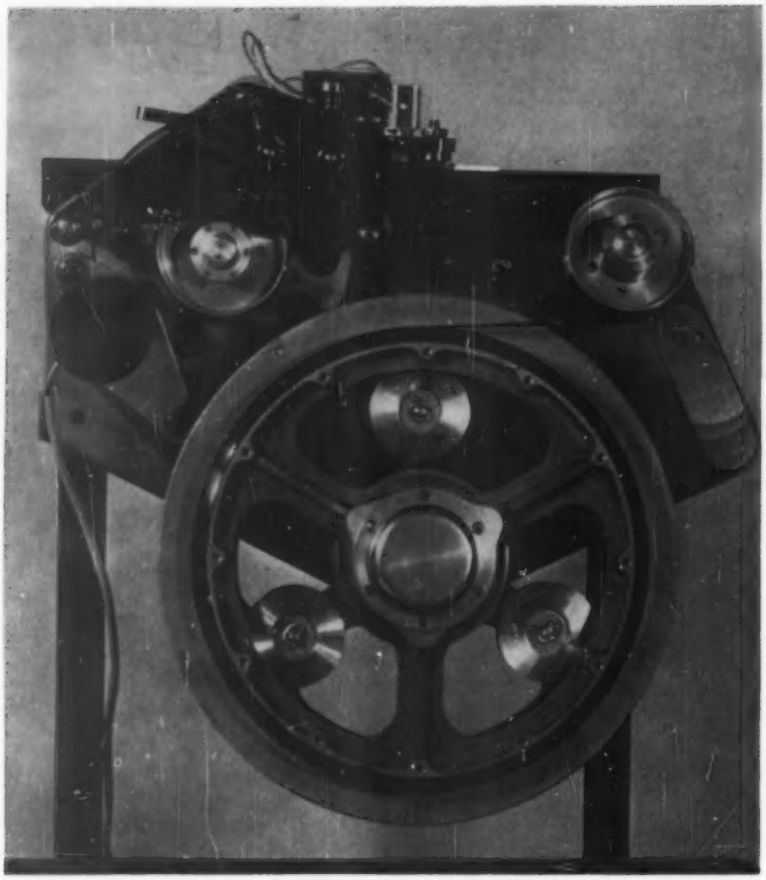

Fig. 6. Tape recorder.

This type of beacon has been successfully employed by National Aeronautics and Space Adm. and the Jet Propulsion Laboratory in previous space flights. Its use would utilize existing ground-station equipment.

Clock and Control Circuits. The clock would furnish all timing functions not supplied by command from the ground. It would supply synchronization pulses for the camera and control pulses to the switching circuitry. Its design would vary, depending upon the desired program functions. Again, it would use stabilized transistor circuits. The control circuitry would handle both programed and command switching.

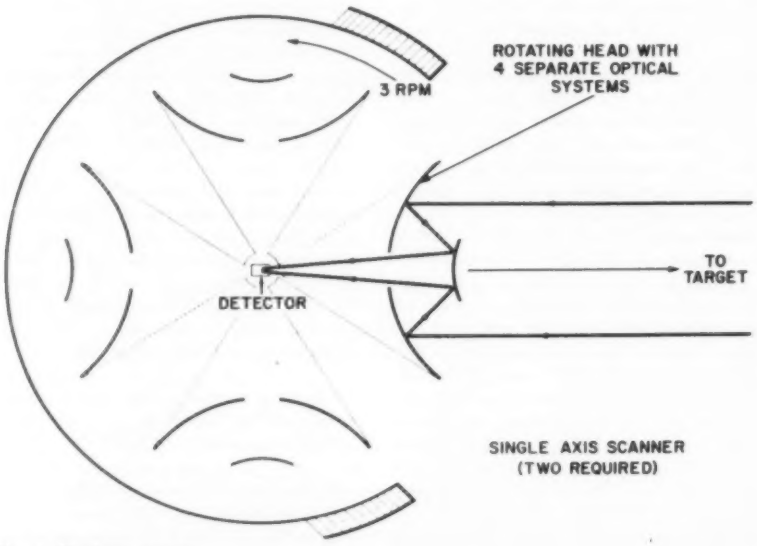

Fig. 7. Horizon sensor.

Infrared Scanner. The scanners described here were designed for the lunar probe to provide error signals for the stabilization system and range data for firing the retrorockets (at approximately 500 miles); simpler systems could be suggested if only range data are required. One narrow beam scans across the front of the vehicle through a 90° arc; the initial time and the final time that the Moon image is in the beam are accurately determined. If these points are not equally spaced from the longitudinal axis, an appropriate error signal is generated. The total time the Moon is scanned is a measure of the apparent Moon diameter, which corresponds to a given range; when a predetermined diameter has been reached, the retrorockets can be automatically fired. A second scanner operates in a similar manner at right angles to the first; the two scanners thus measure both the pitch and yaw. The infrared scanners are sensitive enough to detect the edge of the Moon even though the edge is not illuminated by the Sun (Fig. 7).

The angular width of the Moon from horizon to horizon is a measure of the altitude, since the Moon's radius is known. The accuracy of the measurement therefore affects the accuracy of determining the altitude. The scanner also generates signals for steering the longitudinal axis of the vehicle to the local vertical. The errors in sensing the center point of the scan along with certain steering errors will determine the accuracy of the stabilization to the local vertical. Any off-vertical component will affect the accuracy of altitude determination.

An error analysis accounting for these sources of error is included below.

The approximate weight of the scanning system would be 10 lb, its volume 150 cu in., and its power requirement 20 w. Table I gives the main characteristics of the scanner.

Power Supplies. Power will be supplied by chemical batteries. The total power requirement will be approximately 1550 w. Assuming an operation time of one-half hour, a 775-whr capacity will be required.

Weights. Table II indicates weight and power for various units. The total weight of the electronics package is estimated to be about 142 lb, not including payload framework.

Ground-Station Equipments. Two receivers would work from a 60-ft dish. The tele-

Table I. Specifications of Infrared Scanner.

Detector Element
- Type: Thermistor Bolometer
- Size: 2 × 2 mm
- Noise equivalent power (NEP): 8×10^{-9} w
- Time constant: 2.5 msec

Optics
- Type: Cassagrain
- Diameter: 4.5 cm
- F-number: 1.0
- Field of view: 2.5°
- Focal length: 4.5 cm

Scanner
- Scanned field: 90°/element
- Elements/scanner: 4
- Scan speed: 3 rpm
- Scan time: 5 sec/element

Signal amplifier
- Bandwidth: 100
- f_2: 20 cps
- f_1: 0.2 cps
- f_0: 2 cps

vision receiver would operate in the 240-mc band and would consist of a parametric preamplifier and receiver. The beacon receiver in the 960-mc band would be of the type currently used by NASA. This receiver would operate the telemetry recorder.

A vehicle programing unit would deliver command signals to the command transmitter for giving instructions to the control circuits in the vehicle.

The video signals from the television receiver would pass into the FM demodulator which would demodulate the 2.3-kc subcarrier introduced by the tape-recorder circuitry in the vehicle. The television display would be produced on a slow-scan ultraviolet monitor, which in conjunction with a film camera would record the lunar pictures. The camera film strip would have a sufficiently rapid pulldown mechanism to prevent the loss of any pictures. The signals would also be recorded on a tape recorder as a back-up device. Its output could be played into the demodulator and film recorder for photographic copy. This type of equipment has already been designed and built for a satellite project.

The altitude information from the lunar altitude sensor would be multiplexed with the television signal and would be transmitted upon command or in a programed fashion so that it could be transmitted during the record cycle of the tape recorder. A counting type of measurement would be made to determine the portion of the scan cycle subtended by the lunar horizons. This type of equipment is also in use in a satellite project.

Three ground stations would be needed: at Cape Canaveral, Goldstone and Hawaii. These stations are so spaced over a sufficient portion of the earth that, assuming that the shot is timed properly, at least one of them will be in a line-of-sight position with reference to the Moon at the time of approaching impact.

Alternate Approach. The retrorocket retarded payload is one approach to the impact probe. This would be a logical forerunner of a soft-landed probe. However, another possible approach is to use an impacting probe with no slowdown capability. In such a case, less time is available for picture taking and transmission during the fall from a given altitude.

One way to rearrange the parameters and still obtain as many different pictures at equivalent resolution would be to reduce the area scanned in any one picture by about 5-to-1. This would compensate for the reduced time available indicated in Fig. 3. The remainder of the payload would remain the same. Another possibility would be to change the optics by reducing the focal length at constant f-number to achieve a factor of about five, an increase in the area covered per picture with subsequent loss in resolution. This would result in a simpler and lighter optical system but would not hold the promise for potential application of the design to other probes as does the longer-focal-length system.

Circumlunar Probe

The same payload used for an impacting probe could be adapted to a circumlunar pass. The storage of the magnetic tape could be increased to hold 150 pictures. The pictures would be taken as the probe circled the Moon and would be stored until the probe vehicle had returned closer than 100,000 miles from the Earth. The gain of 2.4 in range would allow a 5-to-1 reduction in the power of the transmitter and thus enable 150 pictures to be returned at the battery weight cited in Table II for the impacting probe. The pictures would take $2\frac{1}{2}$ hr to send. During this time the probe vehicle would travel a distance of about 10,000 miles closer to the Earth.

Therefore, with simple design changes in the tape recorder and the transmitter, the same payload would serve to obtain 150 pictures of the Moon's hidden face and return them for recording and analysis on Earth. If the perilunar altitude were 500 miles, the resolution would be 250 ft and the picture size would be 25 miles × 25 miles.

Table II. Power-Weight Chart.

Unit	Weight, lb	Power, w
Camera	6	9
Optics	20	2
Tape recorder	12.5	25
Transmitter	1	20
Intermediate power amplifier (IPA)	1.5	90
D-c converter for d-c–d-c transmitter and IPA	2	22
Power amplifier (PA)	7	1200
Cooling	10	—
D-c converter for PA	30	200
Command receiver	1	0.3
Beacon transmitter	1	0.45
Batteries	30.5	—
Telemetry	2	0.1
Cables and brackets	15	—
Clock and controls	1	2
Lens focus control	0.5	0.2
Retrorocket control	0.5	0.2
Lunar-horizon sensor	1	1
Totals:	142.5	1572.25

Soft-Landed Probe

The soft-landed lunar probe is one in which the landing velocity is controlled by rockets to enable a landing to be made at low speed. While the general control of the landing phase would be left to Doppler inertial elements in the probe vehicle, the monitoring of the landing would be done with an on-board television system.

The pictures sent down as the vehicle hovers or drops slowly should have sufficient detail at low altitudes to show up any landing hazards or especially desirable areas. The system described above for the impacting probe would serve well as a landing control monitor system. The resolution at one-mile altitude would be about $\frac{1}{2}$ ft.

Once the vehicle is landed, the same television system can be used to scan the nearby lunar surface at very good resolution. The television can also monitor the progress of any exploration vehicles sent out from the probe to explore the surface physically.

Summary

A single design of a high-resolution camera system can serve as a basic element in a number of different lunar exploration missions. The design discussed here is based on an optical design, a television camera, a recorder, a transmitter, power supplies, beacon and control elements which have all been designed and built. Only modest effort is required to make the changes necessary for the missions discussed.

Space Technology and Image Sensing: Summary and Conclusions

By SIDNEY STERNBERG
Topic Chairman

A SUMMARY and a few concluding remarks are in order after these papers of the Space Technology and Image Sensing Sessions. I should like to comment briefly on the papers previously presented and highlight those items which I feel are of the most specific interest to members of SMPTE.

Optical tracking is the most accurate of the tracking methods for determining satellite orbits. Its limitations are primarily in acquiring the satellite, due to limited field-of-view, bad weather, and background radiation. However, it is true that, in regard to many of the orbits of our early satellite vehicles, we depended heavily on our world-wide optical net in order to establish the orbital parameters. The theodolites used at AFMTC in Florida in order to obtain tracking data on the Sputniks are subject to improvement because of certain shortcomings: (1) The process of data reduction and computation in converting from film to orbital parameters is too lengthy, and, therefore, of limited usefulness. Television scanning for automatic coordinate readout may be helpful. (2) Telescopes now used for acquisition have a 3 to 4° field-of-view. This should be increased to 20 to 30° for greater light-gathering capacity. Here electronic image-intensifier tubes would be applicable.

In the paper by Mr. Johnson, we see that satellite image-sensing systems are presently being developed for application to meteorology. These include television systems using $\frac{1}{2}$-in. vidicon pickup tubes with resolutions of 500 lines/frame and sensitivity of 0.01 ft-c-sec for daylight observation. This sensitivity is adequate for daylight viewing of reflected white light. However, for viewing at night under starlight, we may require a sensitivity in the order of 0.0001 ft-c-sec. Image-conversion tubes using electronic aperture scan are operable in the white-light regions, perhaps up to 0.7 to 0.8 μ but in the region of longer wavelengths of 8 to 30 μ or even 50 μ, the thermistor used as a direct scanning-spot device appears to be the only way of imaging these longer wavelengths.

With regard to the environment and how it would affect the various types of sensing instruments that would be used, I believe that the browning of optical glass by long exposures to space radiation is a problem. We must be concerned about the effect of ultraviolet and shorter-wavelength radiations on our optical systems. Meteorite damage during long exposure is also an important factor. The extreme sensitivity of the electronic imaging devices to variations in temperature must be improved. Vidicons will operate satisfactorily between 20 and 40 C. Outside of these ranges there will be a degradation in the image quality. The ranges of thermal environments in outer space that equipment must withstand will, I believe, be much greater than this, no matter how carefully we try to control the temperature of the satellite itself. It is rather significant to note that photoconductors and emitter devices are not sensitivie to cosmic radiation. Such devices, as mentioned in one paper, have been tested under a field of 250 roentgens (one mev) of x-ray energy per hour without deleterious effects. On the other hand, silver halide, as we know, is an excellent detector of cosmic radiation.

Another area of extreme importance is that of communications. As Dr. Roman mentions in her paper, we probably will not be able to use photographic film, which must be physically recovered, but will have to depend upon electronic tubes and conversion to video signals in order to transmit the information back to the Earth. Carrier frequencies will probably lie between 150 mc and 10,000 mc, to minimize noise. Full bandwidth scanning will probably not be possible, and slow-speed scanning apertures will be necessary in the longer space probes in order to reduce bandwidths, and to maintain adequate signal-to-noise ratios for available power. Perhaps even some limited filtration and data processing may be possible prior to placing the scanned information on the communications link.

Many new developments are badly needed; the electrostatic phototape development that has been reported is extremely significant. The instruments that we know, such as magnetic-tape recorders, flying-spot scanners, even television tubes, as currently constituted, will not be sufficient to carry out the experimentation that scientific people would like to conduct in outer space. There are many uses in space technology for the skills and equipment represented by the SMPTE. I would like to emphasize a phrase Dr. Friedman used — "There is nothing as real as a picture." If we define image sensing as the detection of images that are both reflected and radiated over a broad spectrum, image sensing in many forms will be our most prevalent and important payload in the exploration of space as well as of our own planet.

The engineer who has in the past contributed through research, development and production to the perfection of the technology of television, I believe, must now return to the laboratory in order to develop new imaging systems for outer-space exploration. Broadcast standards will no longer hold for space use. Greater sensitivity, higher resolution, broader spectral response, more gray levels, a variety of frame rates — requirements unnecessary for present uses — will become essential in space image sensing. A new environment of radiant-heat control, of cosmic rays, of vacuums lower in pressure than any we are presently achieving in our so-called vacuum pickup tubes — an environment where solid metals boil away and become vapors — will require new technology to handle its new problems and to make use of its advantages. I predict the development of a distinct and different array of image-sensing devices from our space efforts in the next ten years, and a most interesting professional experience, particularly for the members of SMPTE.

Presented on October 6, 1959, at the Society's Convention in New York City, by Sidney Sternberg, Astro-Electronic Products Div., Radio Corp. of America, Princeton, N.J.

The Technical Motion Picture as a Means of Communication

By MARGE T. BRISLIN

Development of new techniques for the production of low-budget, fast-process motion pictures has made the use of film of practical importance to business firms for interdepartmental communiques, presentation of reports and other purposes. The use of technical films by International Business Machines Corp. is discussed.

International Business Machines Corp. is producing low-budget, fast-process motion pictures depicting many of its engineering and research projects. Made at several laboratory locations, the films are shown to technical personnel throughout the company to improve communication and stimulate interest. The films have been enthusiastically welcomed by company engineers and scientists who find them a great help in keeping currently informed on new devices, ideas and processes being developed by their colleagues at the various laboratories.

The intent of the engineering motion pictures is to supplement other means of communication among company engineers. Technical reports, bibliographies, library bulletins, personal visits, technical displays and scientific publications such as the *IBM Journal of Research and Development* continue to carry the great mass of technical information; but a motion picture is worth ten thousand words, especially if it can be produced rapidly and at low cost.

In the past, technical films of this nature have taken as long as six months to produce; consequently, by screening time they were apt to be stale and uninteresting, even though of excellent quality. To effect a welcome change, the film-making group in IBM has developed new techniques enabling them to produce a complete film, with synchronous sound, in two weeks, so that current and timely subject information is disseminated among engineering groups throughout the company within a month. This keeps the engineers in close touch with related activities and keeps management, patent people, and other interested parties abreast of the latest developments.

The "you are there" approach has been used in making the films — close-ups of people at work with their equipment. Figure 1 shows an engineer pointing out a wave shape on an oscilloscope. Each film, of about twenty minutes' duration, contains seven to ten subjects. After a subject has been selected and a draft for the presentation has been prepared by the script writer in cooperation with the engineer, the engineer faces the camera in his own project area. Rehearsals are not held because they tend to make the "actors" nervous and stiff.

The engineer explains and demonstrates each point with the aid of charts, blackboards, oscilloscope displays, and models — using the prepared script only as a guide to insure covering all points, and not necessarily using its exact wording. Simple animation techniques have been devised for use in explaining internal machine operations. Each scene may be re-shot to obtain the desired effect. The whole process — script preparation, discussion, setting up, shooting — rarely takes up more than four hours of an engineer's time.

One of the significant benefits of this type of film presentation is the contact it effects between the presenting engineer and the viewers. The film establishes a closer acquaintanceship among colleagues who may never see each other personally; and, as many engineers have commented, it facilitates meetings when they do take place. In addition, the films provide another vehicle for personal recognition of the contributing engineers and their areas, as well as an incentive for possible future presentations by the viewers.

Technically significant in the production of these films is the development of the single-system technique — sound and pictures are exposed on the same film simultaneously. Furthermore, this technique has been developed in such a way as to make it possible to cut and edit the film and still have the pictures and sound coordinated. This one technique is the biggest time and expense saver in the processing of these films. The cost is low, and there are considerable indirect savings in travel and other communications expenses.

In a typical film, one subject may have as many as eight scenes, and the action is planned with a transition between each scene. The camera crew (Fig. 2) consists of two or three persons: a cameraman

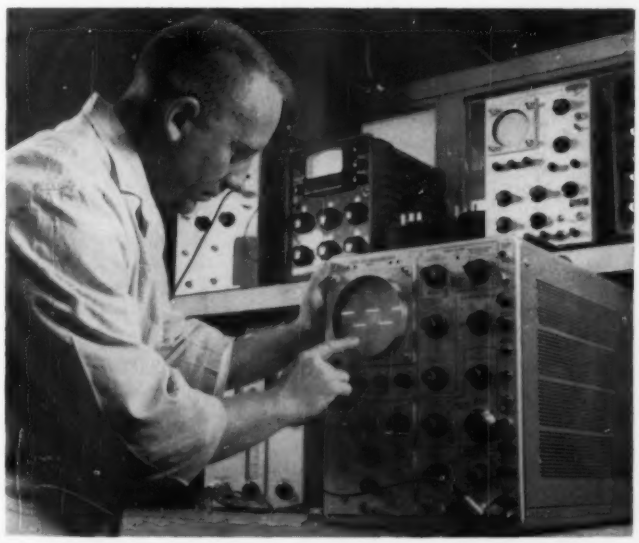

Fig. 1. Engineer points to wave shape on oscilloscope during filming of technical motion picture.

A contribution submitted on July 7, 1959, by Marge T. Brislin, IBM Product Development Laboratory, Poughkeepsie, N. Y.

Fig. 2. Camera crew at work. Author (seated right) is acting as director.

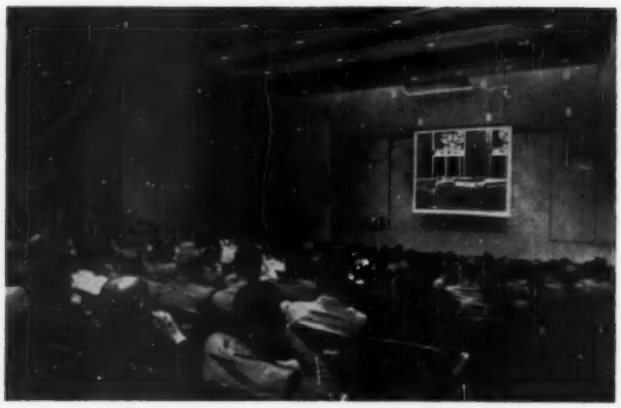

Fig. 3. Group of engineers viewing technical motion picture.

and a writer-director who may also operate the sound equipment or, if not, a third person to handle this equipment.

Since filming is done in project areas, careful control of shooting time and high-quality, dependable equipment are essential. The camera is a single-system Auricon Super 1200 with a ground-glass focusing system which permits focusing through the lens for close-ups. This system records the soundtrack on the film simultaneously with the picture. The film used is Du Pont High-Speed Rapid Reversal Motion Picture Film 931A. Editing, then, is just a matter of splicing the good *takes* together to achieve a complete picture with sound. A Pan-Cinor lens attachment allows continuous movement from a wide-angle shot at 17mm to a telephoto shot at 70mm, while maintaining focus. This type of shot is visually pleasing and permits a close look at details.

Today's engineer is swamped with material designed to keep him abreast of developments in his field. Filming reports helps to ease this burden, and IBM has found this a satisfactory method of covering a variety of subjects in a short time. Figure 3 shows a typical group of engineers viewing a technical film.

A significant sidelight of the technical film program is the development of a projection cabinet built in an IBM model shop. A busy executive may find it inconvenient to set aside 20 minutes of uninterrupted time to view a motion picture. The projection cabinet enables him to view the film by lifting the lid of the cabinet and turning a switch (Fig. 4). The film is projected on a screen inside the lid and the picture can be turned on or off as the viewer wishes.

Fig. 4. Executive views technical motion picture on projection cabinet.

standards and recommended practices

Proposed SMPTE Recommended Practice

A Proposed SMPTE Recommended Practice, Density and Contrast Range of Monochrome Films and Slides for Television, is published here for a three-month period of trial and criticism. All comments should be sent to J. Howard Schumacher, Staff Engineer, prior to May 15, 1960. If no adverse comments are received, the proposal will then be submitted to the Society's Board of Governors for approval as an SMPTE Recommended Practice. — *J.H.S.*

Proposed SMPTE Recommended Practice RP 7

Density and Contrast Range of Monochrome Films and Slides for Television

Introduction

This Recommended Practice originated in the Prints for Television Subcommittee of the Television Committee. The purpose of the recommendation is to promote uniform, high, technical quality of television programs on films and slides by specifying density values which are most desirable for effective television transmission.

Although this Recommended Practice is suitable for the iconoscope as well as the vidicon, the density requirements have been chosen primarily for a vidicon camera chain having an overall gamma of 0.4. This value includes the vidicon with its gamma of approximately 0.65. It correctly compensates for a normal receiver kinescope with a gamma of 2.5. The recommended values are intended to produce the best picture on the home receiver. The achievement of optimum picture reproduction requires not only proper print quality and density but also the cooperation of the artist, production directors and technicians in matters such as make-up, composition, lighting, and exposure of negative as well as proper adjustment of the television system. It has been the experience of the members of the committee that any attempt to correct for shortcomings in one step by introducing nonstandard techniques in another, will usually result disadvantageously.

Recommendations

1. *Scope*

1.1 This recommendation specifies important density values of black-and-white 16 and 35mm motion-picture film and slides intended for television transmission.

2. *Density Requirements*

2.1 The density of significant highlight areas shall have a normal value of 0.4 and shall be not less than 0.3 for optimum reproduction in the television system.

2.2 The density of the darkest significant areas shall have a normal value of 1.9 and be not greater than 2.0.

2.3 The density of human faces, usually observed more intently than other picture areas, shall be in the range of 0.60 to 0.80 unless special effects are desired. These density values are important in order to preserve the proper density relationships between face tones and subjective whites in the scenes.

2.4 The method of density measurement shall be in accordance with American Standard Method of Determining Transmission Density of Motion Picture Film, PH22.27-1947, or the latest revision thereof approved by the American Standards Association, Incorporated.

Notes:

1. It is recommended that proper laboratory practice and care be employed in making negatives and positives to minimize spots, streaks, scratches or other physical defects.

2. The following Society-sponsored American Standards apply to the dimensional values for film and slides for television:

(a) *Picture Area — Motion-Picture Film.* The television picture area of 35mm and 16mm motion-picture film shall be in accordance with American Standard Television Picture Area — 35mm Motion-Picture Film, PH22.95-1954, and Television Picture Area — 16mm Motion-Picture Film, PH22.96-1954. or the latest revisions thereof approved by the American Standards Association, Incorporated.

(b) *Soundtrack.* The photographic sound record on 35mm and 16mm motion-picture prints shall be in accordance with American Standard Photographic Sound Record on 35mm Prints, PH22.40-1957, and Photographic Sound Record on 16mm Prints, PH22.41-1957, or the latest revisions thereof approved by the American Standards Association, Incorporated.

(c) *Film Dimensions.* The film width, perforations, sprockets, etc., shall be in conformance with American Standards or SMPTE Recommended Practices.*

(d) *Television Slides.* The dimensions of slides to be used for television transmission shall be in accordance with American Standard Slides and Opaques for Television Film Camera Chains, PH22.94-1954, or the latest revision thereof approved by the American Standards Association, Incorporated.

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* A complete Standards Index is available from Society Headquarters.

87th Semiannual Convention and Equipment Exhibit
May 1–7, 1960, Ambassador Hotel, Los Angeles

The Ambassador Hotel, scene of several of the Society's most successful Conventions, has been chosen as the fitting environment for the 87th Convention. . . a Convention which, even at this early date, has great promises.

Convention Theme: New Techniques for Films, Television and Video Tapes

Herbert E. Farmer is Chairman of the Papers Program which by the first of the year was already being brought into form. Topics and Topic Chairmen were listed in the November 1959 issue of the *Journal* (p. 772). There is a possibility that additional topics may be developed. The Advance Program will appear in the March Journal.

(Note to prospective authors: There is very little time, indeed, almost no time at all, before Author Forms must be in the hands of the Program Chairman. February 15 is the deadline. So it is most important that all Author Forms be submitted to the appropriate Topic Chairman or to Program Chairman Herbert E. Farmer, c/o Cinema, Univ. of Southern Calif., Los Angeles 7, before that date.)

Ralph E. Lovell, Chairman for the topic of television recording, has reported that a paper on "Thermoplastic Recording" is expected to be presented by Dr. W. E. Glenn of General Electric. A brief story on this new development appears in the New Products column of this issue of the *Journal*. Dr. Glenn will describe the technical details of this process, the announcement of which has aroused wide speculation as to its significance and future applications.

Another event of considerable interest to members will be presentation of a progress report on Video-Tape Standardization by Charles Anderson of Ampex. Other papers on television subjects are expected to deal with color recording machines and various aspects of photographic recording. Papers on educational television are expected to deal with the technical details of educational TV installations.

The motion-picture short subjects, which supplement and enhance the Papers Program, will be arranged by William E. Gephart, Jr., General Film Laboratories.

Krafft A. Ehricke
Guest Speaker

An important announcement from SMPTE President Norwood L. Simmons is that a distinguished guest speaker, Krafft A. Ehricke, of Convair Astronautics, will deliver an address at the Evening Session of Space Age Motion Pictures. He is expected to speak on "Photoreconnaissance of Our Solar System." The Evening Session will be one of general interest

following a day-long presentation of papers on subjects related to the Space Age. This day-and-evening Session is currently planned for Tuesday, May 3. Papers are being assembled and details arranged under the guidance of Topic Chairman Lloyd T. Goldsmith.

Mr. Ehricke is Director of the Vega and Centaur upper-stage rocket programs for Convair (Astronautics) Division of General Dynamics Corp. A native of Germany, he helped develop the German V-2 ballistic missile during World War II. When the war ended, he came to the United States to participate in the U.S. Army's missile and rocket development program. He has been associated with Convair since 1954. He is a consultant to the Office of the Secretary of Defense and a member of the Research Advisory Committee on Electric Power Plant Systems of the National Aeronautics and Space Administration. In addition to his other activities he is now working on a three-volume textbook on space flight.

The Convention Equipment Exhibit

Plans for the Exhibit are well underway due to the energetic leadership of Chairman Harry Teitelbaum. The next report on 87th Convention plans will discuss the forthcoming exhibit in more detail. Detailed information will soon be in printed form and available from Society headquarters and from Harry Teitelbaum, c/o Hollywood Film Co., 956 Seward St., Hollywood 38.

Convention Committee Appointments

Robert G. Hufford is Local Arrangements Chairman. The roster of chairmen which Mr. Hufford has worked out for putting on the Convention include those listed below as already appointed by Convention Vice-President Reid H. Ray.

Local Arrangements Vice-Chairman: *Ralph E. Lovell*, NBC

Administrative Assistants: *Edward P. Ancona*, Motion Picture Research Council; *Howard R. Bell*, Mole-Richardson Co.; *Robert W. Bishop*, Eastman Kodak Co.; *Glenn R. Osborn*, USAF; *John G. Stott*, Eastman Kodak Co.

Banquet: *G. Carleton Hunt*, General Film Laboratories
Exhibits: *Harry Teitelbaum*, Hollywood Film Co.
Hospitality: *Theodore B. Grenier*, American Broadcasting Co.
Hotel Arrangements: *Dennis F. Godfrey*, W. J. German, Inc.
Ladies Program: *Mrs. Robert G. Hufford* and *Mrs. Norwood L. Simmons*
Luncheon: *Alan M. Gundelfinger*, Technicolor Corp.
Membership: *Harry J. Lehman*, Cine-Tel Productions
Projection: *Don V. Kloepfel*, General Film Laboratories
Public Address and Recording: *William H. Stutz*, Magnasync Mfg. Co.
Publicity: *Jack Goetz*, Consolidated Film Laboratories
Transportation: *Russ Landers*, General Film Laboratories
Auditors: *Arthur Johnson*, Pathe Labs Inc.; *Richard S. Rogers*, Consolidated Film Laboratories
Registration: *Arthur Jacobs*, Jack Wrather Productions; *Robert Creamer*, General Film Laboratories

Rates and Reservations information will be included in the Convention announcement which will be mailed to all members within the next month. Cards for hotel reservations and pre-registration for the Convention will be included in this mailing. Another item relevant to rates concerns the *1960 Annual Conference of the Society of Photographic Scientists and Engineers* which will be held May 9–13 at the Hotel Miramar in Santa Monica. The Society and the SPSE society are privileged to attend the convention of the other on a membership basis in respect to registration rates.

INTERNATIONAL CONGRESS 1960 5TH SMPTE ON HIGH-SPEED PHOTOGRAPHY

Since the last report on Fifth International Congress activity was published in the December *Journal*, considerable progress has been made, particularly in the coordination of efforts of Congress planners in the various participating countries. Author forms are available from Society headquarters and Chairmen previously listed.

Appointment of an additional Topic Chairman has been announced. The new Chairman is **Vernon E. Taylor** of the National Institutes of Health. This appointment is of particular interest because of the importance of high-speed photography as a tool of medical research. Considerable planning has been directed toward emphasizing this application of high-speed photography and papers on this subject are expected to attract substantial interest from the general public as well as from practitioners in the field. Mr. Taylor is also President of the Maryland Industrial Photographers Association.

Even at this early date, the spirit of cooperation and enthusiasm evident from a number of sources has been gratifying. A French publication, *Mesures & Controle Industriel* published, in its November issue, a most attractive story on the Congress; and in a number of ways from a number of countries expressions of interest and anticipation have been received. It is expected that at least twenty countries will be represented at the Congress.

One change in the roster of delegates (September *Journal*, p. 638) should be noted. **Dr. R. F. Saxe,** Hon. Secretary, National Committee for High Speed Photography, Queen Mary College, Mile End Rd., London, E.1, replaces **W. D. Chesterman** as the Delegate from Great Britain.

Max Beard, chairman of the Fifth International Congress, has been presented the Meritorious Civilian Service Award of the U. S. Navy in recognition of "unusual skill and leadership in directing the operations of the Photographic Division" of the U. S. Naval Ordnance Laboratory. The Citation accompanying the Award notes that Mr. Beard's "efforts have resulted in valuable and continuing contributions to the Laboratory's development, research and evaluation programs." It also notes his "initiative, resourcefulness and foresight" in developing "a highly flexible program of providing specialized photographic techniques and complete photographic instrumentation systems to meet the Laboratory's varied demands."

Education, Industry News

A $7-million experiment in educational television began late in October when Purdue University, Lafayette, Ind., filed application with the FCC for the Midwest Council on Airborne TV Instruction (MCATI). As reported by the *Television Digest*, Nov. 2, 1959, plans are to transmit on channels 72 and 78 for standard TV signals and channels 75 and 76 for narrowband — 3-mc for the time being. All airborne transmitters will be 12 kw, each feeding into a separate omnidirectional antenna. Signals will be sent to the plane from Purdue by 12-kw transmitters (28.2-kw ERP)—channels 41 and 47 for standard transmission and channels 53 and 59 for narrowband. Of the hundreds of schools to participate in the test, 10 will have special narrowband receivers. Two DC-7 planes will be used, one of them as a standby. The transmitting plane will travel in a 10-mile radius, circling 23,000 ft above Montpelier, Ind., 140 miles from the Purdue campus.

An interesting aspect of the program is spectrum conservation. Engineers who prepared the application stated: "The broadcast of six programs on separate standard 6-mc channels would require the use of a total of 36 mc of spectrum space by each facility and might preclude the use of additional spectrum space in nearby areas because of the various problems of interference. Complete coverage of the country could be achieved with three groups of six channels each, or a total of 108 mc of frequency spectrum. A fundamental part of the proposed experiment would be to determine means of reducing the spectrum requirements and of estimating the overall requirements."

An undersea color motion-picture camera with a depth range of 25,000 ft is expected to bring up from the bottom of the ocean a strange and perhaps terrifying story of creatures burrowing in the floor of the world and monsters of the deep never seen or even imagined by Man.

The camera (first named the Halibut and then renamed the Deep-Sea Camera Sled and known also as the Troika) was devised by Harold E. Edgerton of the Massachusetts Institute of Technology working with Jacques-Yves Cousteau, leader of Calypso undersea expeditions and producer of *The Silent World*. It was built with a research grant from the National Geographic Society. The hydrofoil housing was designed and constructed by the French Undersea Research Center at Marseille. The unit was first named the Halibut because of its flat-bellied shape and the two "eyes" on top of its head — one a pressure-resistant 35mm color motion-picture camera, the other an electronic flashtube synchronized with the camera shutter. The unit is dragged across the sea floor on a braided nylon cable suspended from the ship. It has been designed to pass over small obstacles without fouling. When stopped by something larger the unit is constructed so that it automatically disengages itself and can be drawn on board.

A four-day Seminar and Workshop on Animation Film Technique will be held in New York in June 1960. Sponsors are Florman & Babb, Inc. and the Warren C. Portman Co. The F & B Triplex and Portman Animation stands will be used to demonstrate the production of films. The Seminar is planned primarily for the small film producer who is inexperienced in animation techniques. The sessions will be conducted by experts in the field, and arrangements will be made to visit leading animation studios. There is no charge for the course. Additional information is available from Charles Lipow at Florman & Babb, Inc., 68 W. 45 St., New York 36. The first Seminar is limited to an attendance of 100.

A three-award film, *Fire and Explosion Hazards With Flammable Anesthetics*, is a production of Mervin W. La Rue, Inc., 15 E. Chicago Ave., Chicago 11, a firm which specializes in the production of medical motion pictures. The awards: the Bucranio di Bronzo, presented at the Fourth International Exhibition of Scientific Films (a section of the Venice International Film Festival); a Special Award, voted by the 1959 Clinical Congress of the American College of Surgeons; and second place at a film competition at the annual meeting of the Biological Photographic Association in Montreal.

Plans for a cooperative television network linking the United States with Central America have been announced and a conference is scheduled to take place in New York City, Feb. 3–5, when details will be discussed. The network would take in El Salvador, Guatemala, Nicaragua Honduras, Costa Rica and Panama. Leonard H. Goldenson, President of American Broadcasting—Paramount Theatres, Inc., and Frank Marx, ABC Vice-president for Engineering, participated in the initial meetings.

Engineering by Edward H. Robie is No. 14 in the Vocational and Professional Monograph Series published by Bellman Publishing Co., P.O. Box 172, Cambridge 38, Mass. The 36-page pamphlet, priced at $1.00 gives practical information of interest to the young person choosing a career. It takes up the scholastic training needed, employment opportunities, remunerations, opportunities for advancement and other informative details.

American Standard Method of Measurement of Television Luminance Signal Levels, C16.31-1959, has been approved and published as an American Standard. Developed by the Institute of Radio Engineers, the Standard describes methods of measuring the significant amplitude levels of a monochrome or color television signal, either composite or noncomposite. It is also identified as an IRE standard, 58 IRE 23, Sl, replacing Part 1 of standard 50 IRE 23, Sl. This Standard became necessary because of the standardization of color television signals in the United States, and the inadequacy of the earlier Standard in providing methods of measuring the luminance component of the color signal. It consists primarily of a change in the response characteristics of the oscilloscopes to insure adequate suppression of the color subcarrier. It is available from the American Standards Association, Dept. PR 108, 70 E. 45 St., New York 17, at a price of 60 cents.

A 35mm color film on music of the colonial period, a Colonial Williamsburg Inc. production, is scheduled for next spring. Provisionally titled *Music of Williamsburg*, the 27-minute film will be directed by Sidney Meyer, director of *The Quiet One* and other notable motion pictures. Stan Croner is author of the script. The film is planned primarily for television. It will also be available to classroom and club audiences. This film will be the first issue under the organization's expanded audio-visual program.

The Independent Television Authority's new transmitting station at Black Mountain, near Belfast, Ireland, began operation October 31. Transmitting and studio equipment was supplied by Marconi's Wireless Telegraph Co. of Chelmsford, England. The installation includes two 4-kw vision transmitters Type BD.366 and two sound transmitters Type BD.270A, together with combining units, Program input equipment, flying-spot caption scanner, control desk and test equipment. The Black Mountain station will operate in Channel 9 at a vision frequency of 194.74325 mc and a sound frequency of 191.230 mc.

Miniaturization is one of the "new" words coined by some anonymous wordsmith to express a rapidly developing technological trend. An article in the December issue of **Coronet,** "Mighty Midgets of the Space Age," by Jack Long, discusses this new trend. "Our engineers are hard at work," he reports, "Making things smaller and smaller — 'thinking little,' they call it." Among miniaturized products mentioned in the article are miniature TV cameras which will "soon be transmitting pictures back to earth from circling satellites." Another miniaturized TV camera, now under development at the University of Melbourne, Australia, will be small enough to be swallowed and will be used in diagnosing stomach disorders. Pictures of the patient's "interior" will be displayed on a screen and will be magnified 30 to 40 times.

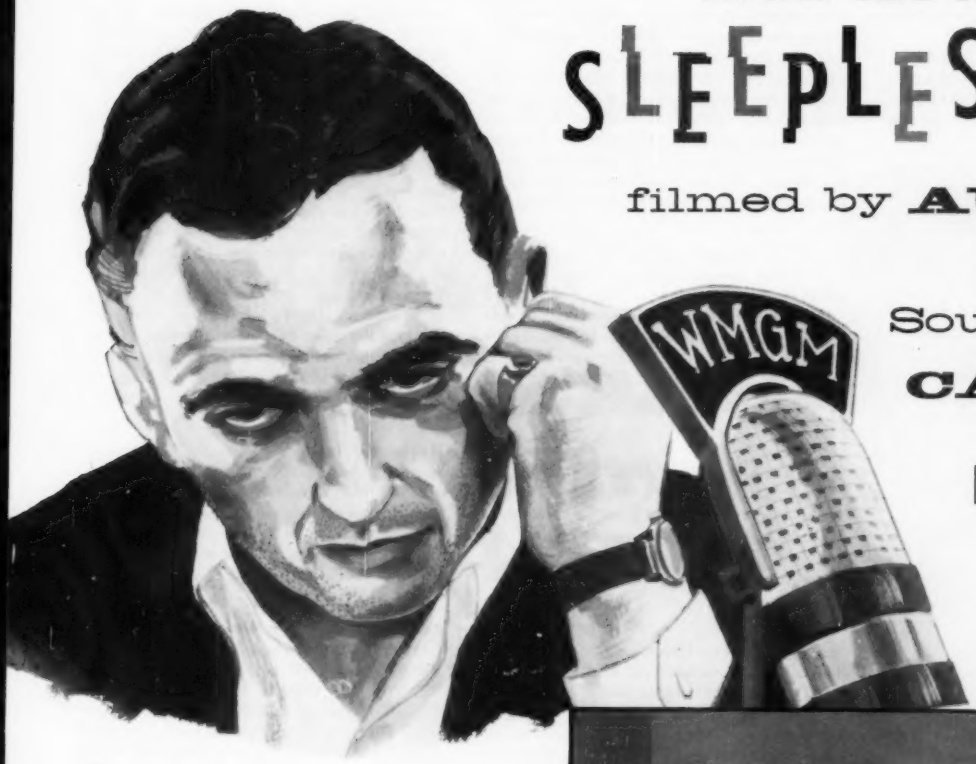
Special awards for the successful results of "thinking little" are granted by a national Miniaturization Award Committee organized by Horace D. Gilbert, President of Miniature Precision Bearings, Inc. The 1959 Miniaturization Award was presented to the Martin Co. of Baltimore, Md., for a 5-lb atomic battery.

Collectors of "moviana" and experts in motion-picture history should be introduced to Chet L. Switell, 2946 Watseka Ave., Los Angeles 34. In a letter to the *Journal* Editor, Mr. Switell writes, "I wonder if your members may have any motion-picture historic material for sale or exchange or for that matter, any entire collection of motion-picture equipment of some historic value. This of course would include old manuscripts, books and fan magazines and the film trade journals of early motion-picture days. Any and all

201 hours of SLEEPLESSNESS

filmed by AURICON 16 mm Sound-On-Film CAMERA

Auricon Hollywood



Peter Tripp, Ace Disc Jockey for New York Radio Station WMGM, is depicted above after he completed a record 201 hours of sleeplessness in an amazing test of the human body!

This unequaled "Sleep Deprivation Study" was observed by Psychiatrists and Space Medicine Experts who acclaimed the experiment as an important contribution to scientific knowledge.

Mr. Tripp was filmed during every hour of his 8 days of sleeplessness by the quiet "self-blimped" Auricon 16mm Super-1200 Sound-On-Film Camera, and the resulting Sound-Pictures were released daily for viewing.

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Mr. J. A. TANNEY, (left), President of S.O.S. Cinema Supply Corp., New York City, (Auricon Sound Equipment Dealer for 20 years), furnished the Auricon 16mm Super-1200 Sound-On-Film Camera, shown above. Here he discusses the amazing Sleeplessness experiment with Peter Tripp, shown before the start of the grueling 201 hour test.

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letters on historic motion-picture collections will be answered...."

Mr. Switell also advises that he has for sale a 1907 Edison projector in good working condition and would be pleased to consider an offer from some interested collector.

The International Conference for Standards on A Common Language for Machine Searching and Translation was held Sept. 6-12, 1959, at Cleveland, Ohio. The Conference was sponsored by Western Reserve Univ. and Rand Development Corp. Papers presented covered three main subject areas: (1) Analytical description of operational, pilot, development or research systems programs for the machine searching and/or machine translation of wide subject areas of scientific and technical literature. (2) Analytical description of equipment in operation or under development for the machine searching and/or machine translation or scientific and technical literature. (3) Analytical and detailed presentations of research in progress, or proposals, for common machine language developments directed to the establishment of standards of interconvertibility among machine searching and/or machine translation systems.

The International Federation for Medical Electronics is a new organization formed to consolidate activities in the field of medical electronics, according to information received from the Medical Electronics Center, Rockefeller Institute, 66 St. and York Ave., New York 21. The new organization was formed during the Second International Conference on Medical Electronics held in Paris at UNESCO House, June 24-27, 1959. The IFME will encourage world-wide development and dissemination of knowledge in medical electronics. It will sponsor international congresses at regular intervals, collect and publish literature, encourage research and generally foster international collaboration in the field.

Wells R. Chapin has been appointed to the newly created post of Manager of Marketing for Dage Television Div., Thompson Ramo Wooldridge Inc. He was formerly Chief Engineer for the St. Louis stations KSLH and WIL. He has also been associated with General Electric and has been a field engineer for Raytheon Manufacturing Co.

Two new appointments to Chrysler Corp.'s Motion Picture, Radio and Television Service have been announced: Robert J. Shafer has been appointed supervisor of radio-television news and Kendrick W. Williams is supervisor of production.

Sidney Weiser, Chief Engineer for USI Robodyne, a division of U.S. Industries, Inc., has been appointed Director of Engineering. He was formerly Director of Research for Federal Manufacturing and Engineering Co. and has been interested in a wide variety of products and systems, including magnetic-tape recorders, cameras, microphones, automatic slide changers, actuating mechanisms, air-conditioning apparatus, electric heat generators, and mechanical presses with interlocking controls.

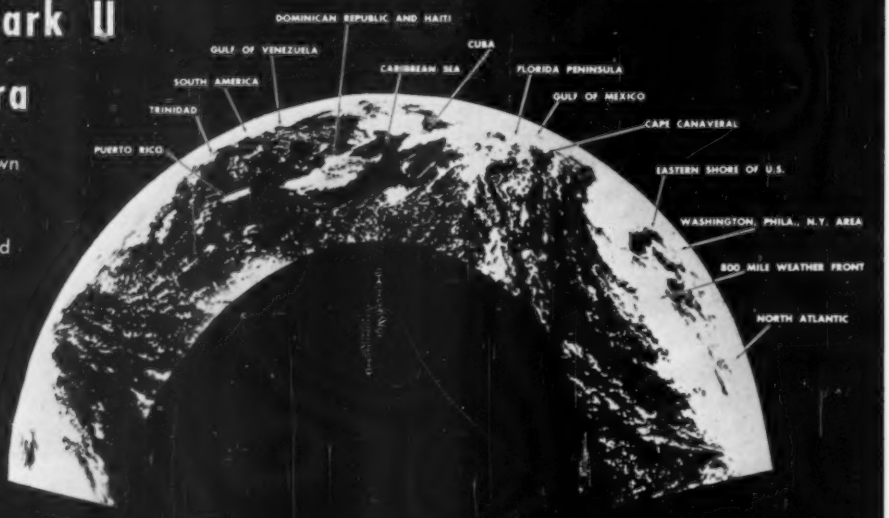
Oliver E. Cain has been appointed to the newly created post of Special Representative for S.O.S. Cinema Supply Corp. He has just returned from Caracas, Venezuela, where he has been active in the film and television industries. He has served as Managing-Director of Tiuna Films C.A. and General Manager of Telefilms C.A., both in Caracas. He was recently executive director of the Venezuelan television news program, *El Observador*, which was awarded a prize for the best news coverage in that country.

Herbert Pilzer, of Motion Picture Enterprises, Inc., has been appointed Executive Coordinator of the Association of Cinema Laboratories. Activities will include formation of a committee to study fair trade practices for motion-picture laboratories in the United States.

Jennings B. Dow, a director of Hazeltine Corp. has been elected President of its newly organized subsidiary, Hazeltine Research Corp. R. K. Hellmann has been elected operating Vice-President and Technical Director. Frederick R. Lack has been consultant to the new organization. Plans include research in electronics applicable to both military and civilian fields.

The ACR Mark II Space Camera

has been successfully flown in the Atlas and Thor missiles. This camera has produced pictures of amazing resolution from altitudes up to 700 NM, and has enjoyed a 100% reliability factor.



Mosaic made from films obtained by ACR Space Camera in General Electric Mark 2 re-entry vehicle flown on Atlas 11C Missile, 24 August 1959. One-sixth of the earth's surface is shown.

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CLEANS your film and tape

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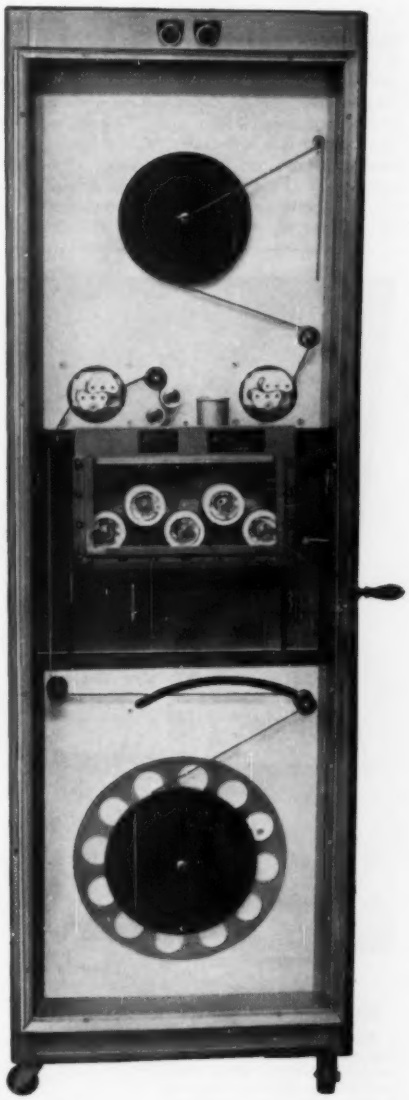

All you have to do is put the film in place and fill the solvent tank. The new Unicorn cleaner does the rest automatically—and speedily with all scrubbing action taking place below the solvent level. It effectively cleans motion picture films (negative and positive) and magnetic tape at rates to 300 feet per minute with complete safety. Cleaning is accomplished by counter-rotating velvet covered scrubbing rollers, effectively removing dirt, lint, oil, fingerprints and wax.

The Model A-5100 is a combination 16/35 mm film cleaner. Other cleaners are available for 16 mm film only, 35 mm film only and for 70 mm film only. All models include these special features:

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section reports

The Atlanta Section met on December 8 at the Kodak Processing Laboratory, Chamblee, Ga., with an attendance of 38.

Lloyd Armbruster, Technical Supervisor, Kodak Processing Laboratory, Chamblee, Ga., delivered a slide talk, "Color Photographic Materials and Processes," prepared by Dr. Lyle Brewer, Eastman Kodak Co., Rochester, N.Y. The talk reviewed the theory of additive and subtractive colors, the structure of color photographic materials, and the chemistry and equipment involved in the processing to produce the finished color picture.

In addition, a short color movie, "Assignment Jet Colorama," was shown. This picture depicted the taking, printing and installation of the Colorama that is in Grand Central Station in New York.

Before the regular meeting, a short board meeting was held during which some plans for 1960 were formulated. During the meeting, the new officers and board members were introduced. Following the meeting, coffee and doughnuts were served and a tour of the Kodak Laboratory was conducted.—Wesley R. Sandell, *Secretary-Treasurer*, c/o Kodak Processing Lab., 4729 Miller Drive, Chamblee, Ga.

The Boston Section closed its 1959 season on November 19 with a meeting at the WBU-TV studios of Boston University. Ninety-seven members and guests attended the meeting. Dr. Harold E. Edgerton, Massachusetts Institute of Technology, guest speaker, discussed "Photographic Instrumentation Under the Sea," over a closed television system operated by students of the School of Communications. The audience viewed the program on video monitors installed in the meeting area.

At the beginning of the program, Edward H. Rideout, Boston Section Chairman, introduced Alexis Ushakoff, Executive Director and Faculty Advisor, Boston University School of Public Relations and Communications; David Nohling, chief, SPRC Dungeon; Robert Rose; Robert M. Fraser, Secretary-Treasurer, Boston Section; and Dr. Hugh Gillis, Chairman of Division of Communication Arts at the Schools of Publications and Communications at Boston University.

Following the introduction of the panel the television cameras switched to Dr. Edgerton who was interviewed by members of the panel. Dr. Edgerton talked about his trip on the Calypso and demonstrated photographic equipment used for underwater photography. This part of the program was kinescoped.

The second part of the program was conducted in the Boston University Auditorium where Jeffrey L. Myles, manager of Technical Operations at WGBH-TV, Channel 2, Boston Educational Station, discussed "Behind the Scenes of Kine Recording." Mr. Myles spoke on the requirements for good kinescope recordings and illustrated his talk with recordings made over a number of years which demonstrated the improvement in quality obtained by the methods he described.

An interesting discussion period followed his presentation, after which the audience enjoyed coffee and doughnuts through the courtesy of the Keystone Camera Company.—Robert M. Fraser, *Secretary-Treasurer*, c/o ITEK Corporation, 700 Commonwealth Ave., Boston 15.

The Canadian Section met September 10 at the National Film Board Auditorium, Montreal. Approximately 50 members and guests attended.

P. J. Brule of the Minnesota Mining and Manufacturing Company, Toronto, gave an excellent paper on video tape.

Following a coffee break in the National Film Board Cafeteria, there was a panel discussion on the "Operation and Possibilities of Videotape," chaired by R. S. Rekert of the National Film Board Members of the panel were Charles Frenette, Canadian Broadcasting Corporation; G. G. Grahan, National Film Board; and Ralph Foster, Mendelson Films. Many points of the possible uses of video tape were discussed and its aspects in relation to motion-picture film were debated.—R. Ringler, *Secretary-Treasurer*, 85 Eglinton Avenue, E. Toronto, Ont.

The Canadian Section met on November 4 at the National Film Board Auditorium in Montreal with an attendance of 50. Speakers were R. W. Curtis, National Film Board, who discussed "The Testing

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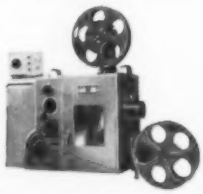

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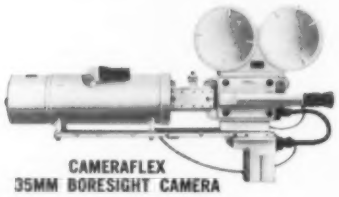

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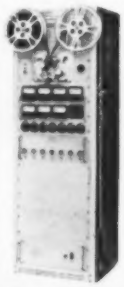

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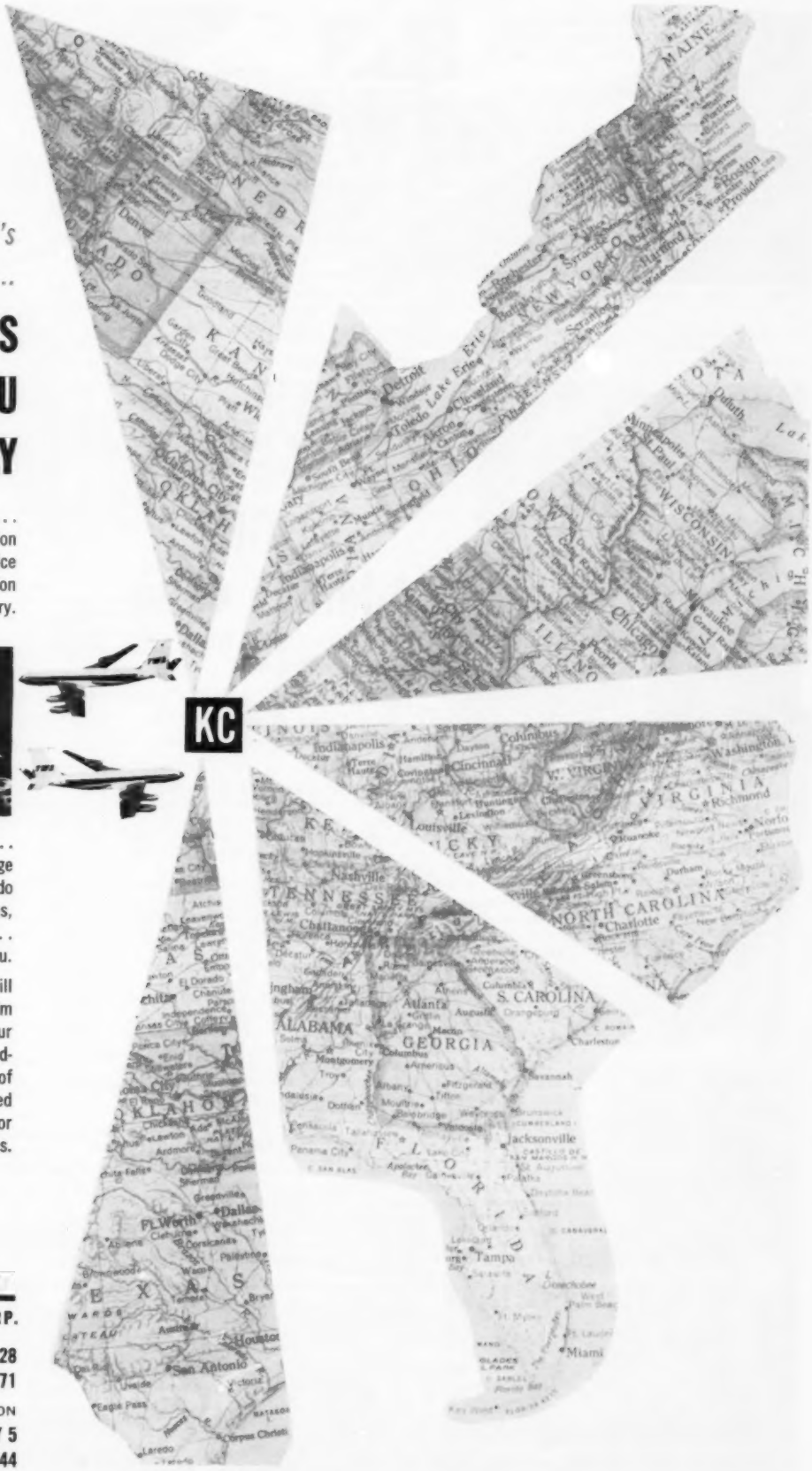

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of Microphones in a Single Enclosure"; and F. R. "Budge" Crawley, Crawley Films, who talked about "R.C.M.P. Series."

The meeting was opened with an excellent short subject, a travelogue on Brazil.

Mr. Curtis outlined and demonstrated the techniques used by the National Film Board to check the characteristics of various microphones. He offered the services of the described apparatus to anyone in the Society who wanted to use it.

Mr. Crawley showed a 35mm print of one of the episodes of the "R.C.M.P. Series" shot for TV by Crawley Films in Ottawa. After the screening he discussed the series from both the administrative and the technical point of view—R. E. Ringler, *Secretary-Treasurer*, 85 Eglinton Avenue, E. Toronto, Ont.

The Canadian Section met December 17 at Cinesound Limited, 543 Rogers Rd., Toronto, with an attendance of 57 members and guests. The three speakers of the evening were L. J. Murch, Harold Wright, and Rodger Ross, all of the Canadian Broadcasting Corporation. "An Engineering Approach to Television Film," was the subject of the discussion.

Under three separate titles, the speakers gave the papers they presented at the 85th SMPTE Convention in May 1959. The three papers appeared in the November, 1959 issue of the *Journal*.

Following the presentation of the National Film, "City of Gold," the first speaker, Mr. Murch, discussed "Standardized Gray-Scale Characteristics for Vidicon Telecine." The need for standardization, the factors of influence and the setting up of test material for use as a scale of comparison were discussed.

Mr. Wright's subject was "Density and Exposure Control for Television Films." A system of making 16mm for television was described. Two main objects are achieved: 1. Predictable output transmission signals for visual materials; 2. tone scale matching of TV live studio and film materials for smooth integration of the two.

"Constant Density Laboratory Process for Television Film," was the subject discussed by Mr. Ross. He outlined requirements for a negative-positive laboratory process to obtain predictable waveforms at the output of a calculated telecine camera chain.—R. E. Ringler, *Secretary-Treasurer*, c/o DuPont of Canada Ltd., 85 Eglinton Ave., E. Toronto, Ont.

The Chicago Section held a two-day special regional meeting on August 21 and 22 at Purdue University, Lafayette, Indiana. The meeting was in conjunction with the University Film Producers Association.

Forty-five SMPTE members joined more than 150 UFPA men and women for a joint afternoon and evening session on the first day and a second day session highlighting in-plant film production. John Ditamore, director, Hall of Music, Purdue University, and Jesse Senn, manager, Purdue Motion Picture Production Unit, were hosts at the meeting.

Following registration in the Memorial Center and welcoming ceremonies, the members were conducted on an extensive tour of the Purdue A-V and TV facilities. In addition to touring the well-known Hall of Music, which is one of the finest and best equipped auditoriums in the country, the members were shown the new building which houses the A-V Center, film production facilities, sound recording studios, experimental theater and a number of lecture theaters and projection rooms.

The complete program of the two-day activities follows:

Friday Evening, August 21:

Teaching with Telemaginuity, Professor J. Collins Orr, Purdue University.

Lightweight Lighting for Motion Picture Productions, Larry Grover, President, Natural Lighting Corp.

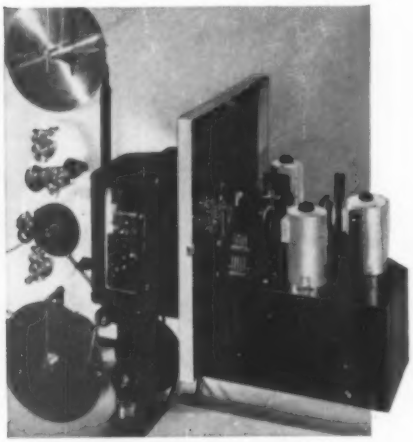
Modern Theater Lighting and Sound Equipment, John Ditamore, Director, Hall of Music, Purdue University.

Saturday Morning, August 22:

Special Report: *In-Plant Production of Applied Motion Pictures*, Kenneth Penney, Minnesota Mining and Manufacturing Co., Harry Paney, Arthur Anderson and Co., Larry Warnock, Link-Belt Co., Julian Ely, Autonetics, Division of North American Aviation.

The Saturday program included many film examples and was followed by a question-and-answer period.

We are especially grateful to our Purdue University hosts and to Jack Moriarity, UFPA President, for their help and cooperation in arranging this meeting.—



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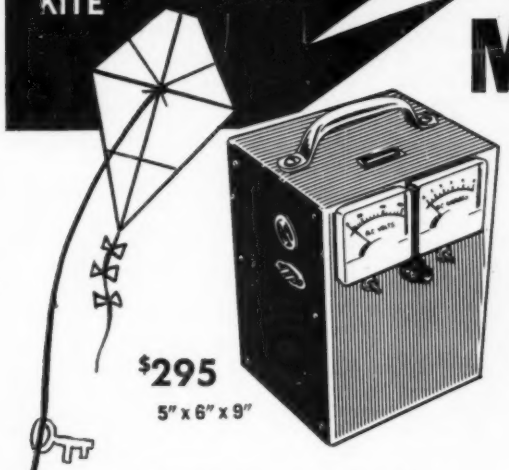

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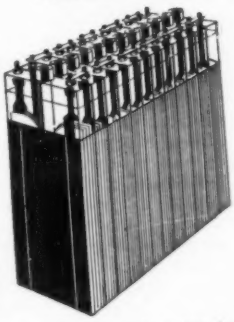

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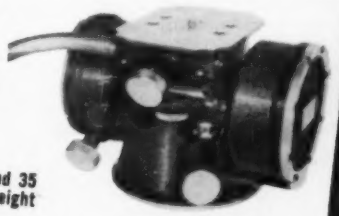

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William H. Smith, *Secretary-Treasurer*, c/o Lakeside Laboratory, Box 2408, Gary 5, Indiana.

The Chicago Section met on October 12 at United Film and Recording Studios in Chicago with an attendance of 85. The speakers were William Rebane, Cinetarium, Inc.; Richare Ranger, Rangertone; and D. J. White, Magnasync.

Mr. Rebane opened the meeting with a demonstration of the Cinetarium process by projecting a 10-minute film to groups of approximately 20 persons at a time. In this technique, a specially made 35mm motion-picture film was projected onto a 360° dome-like screen which enclosed the viewers. Following the demonstration, he discussed the system's potential applications which include training where the effects of peripheral vision are especially important to the trainee.

The second part of the program featured papers presented by Col. Ranger and Mr. White in which they described technical consideration of recording and playing back synchronous sound with motion-picture photography. Col. Ranger related the history and described the method of recording synchronous sound on ¼-inch magnetic tape. The speaker then demonstrates double-system playback of synchronous recording in which the previously recorded "sync" signal on the ¼-inch tape controls the speed of a projector equipped with a variable-speed motor thereby maintaining synchronism between the film projector and the tape playback.

Mr. White, in his presentation, described a portable 16mm magnetic film recorder, various models of which can be attached to most 16mm cameras for synchronous sound photography. The 12-lb recorder can be driven by either the camera motor or its own self-contained motor. Synchronous projection is accomplished on a standard 16mm projector and a 16mm magnetic sound playback unit.

Following presentation of the papers, both speakers answered questions from the audience. Equipment of both types was available for inspection at the close of the meeting.—William H. Smith, *Secretary-Treasurer*, c/o Lakeside Laboratory, Box 2408, Gary 5, Indiana.

The Chicago Section met November 12 in the Prudential Building Foyer with a near capacity crowd of 125 in spite of a heavy snowfall.

Following a pre-session short, "Murder On the Screen," produced by the Calvin Company, Kenneth Mason, Manager, Midwest Division, Motion Picture Film Department, Eastman Kodak Company, presented two papers describing new 16mm and 35mm color films. In his first paper, "A High Speed Color Negative," Mr. Mason described the new type 5250 35mm negative which has been designed to replace Type 5248. With an ASA 50, the new film has twice the speed of the film it replaces thereby simplifying some of the problems of studio lighting and/or making possible greater depth of field in exposure. While the film is compatable with Type 5248 color negative in processing, some differences in the printing characteristics of the two films were noted and described. Color slides were used to illustrate these characteristics and examples comparing the two films were shown.

"Two New Color Reversal Camera Films," was the topic of Mr. Mason's second paper in which he described the new SO-260 and SO-270 high-speed color films. These films, which are of the incorporated color coupler type, have speeds of ASA 160 and ASA 125, respectively, and will be available to both 16mm and 35mm users. The principal advantage of the films is their greatly increased film speed which points to potential application in fields such as sports, missiles, medicine, and industrial photography where sufficient light is frequently not available. This film can be printed through any of the conventional duplicating procedures. In screen examples following the paper the demonstration material included a 5269 print from the high-speed color reversal original as well as some projected samples of the camera film.

As an extra added attraction, and to complete the demonstration films, Mr. Mason projected examples of the new neutral balance Ektachrome which will soon be available. This sample reel, which compared the new and old types and prints therefrom, showed that a marked improvement in color quality is obtainable from the forthcoming film, which is expected to be available after the first of the year.

A brisk question and answer period followed the papers during which Jack Maynard of W. J. German, Inc., joined Mr. Mason to supply answers. William H. Smith, *Secretary-Treasurer*, c/o Lakeside Laboratory, Box 2408, Gary 5, Indiana.

The Hollywood Section met on November 17 at the Moody Institute of Science, West Los Angeles, with an attendance of 240. The speakers were Dr. Herbert Meyer, Motion Picture Research Council, who discussed "The Nature of the Latent Image"; John Waner, Eastman Kodak Company, whose topic was "New High Speed Eastman Color Reversal Film, Type SO-260"; and M. A. Hankins, Mole-Richardson Company, who talked about "Recent Developments in Special Effects Equipment."

Dr. Meyer gave a short discourse on the present status of the photographic theory concerning latent image formation and structure. By use of diagrams in slide form, Dr. Meyer showed the energy levels of the electrons in the silver atom and how exposure from each quantum of energy releases an electron in the silver halide crystal which wanders in the conduction bands. These wandering electrons charge sensitivity specks which ultimately attract silver ions to form developable silver grains.

Mr. Waner gave a brief presentation on the New High Speed Eastman Color Reversal Film. The daylight type has an exposure index of 160 and the tungsten type has an exposure index of 125. A short sample film was projected showing results obtainable under low levels of light.

Mr. Hankins described some new special-effects equipment that Mole-Richardson now has available for studio use. Special fog-making machines of several sizes were demonstrated and a machine for spinning cobwebs was interestingly put into action. The fog-making machines can be used effectively also to distribute insecticides and mist to disperse man-made fog.—Carl W. Hauge, *Secretary-Treasurer*, 959 N. Seward, Hollywood 38.

The Hollywood Section met on December 15 at the Academy Awards Theatre, Los Angeles, with an attendance of 520. Joseph Roizen of Ampex Corporation spoke on "Experiences in Russia With the American National Exhibition."

Mr. Roizen presented a most interesting lecture with color slides, color motion pictures, and audio tapes, both monaural and stereo, of Russian scenes and sounds. In an easy, free-flowing style, injected with a great deal of humor, the speaker unraveled his story without the aid of notes or script.

When plans for the trip had taken on a definite aspect and Mr. Roizen knew that he would be a member of the delegation departing in two months for Moscow, he proceeded to acquire a good working knowledge of the Russian language. He procured a set of Russian language records, as used in college training, and transferred them to tape on his Ampex Recorder. He then spent one hour every day listening to the tapes and practicing pronunciation by recording and comparing his pronunciation with the lessons. The four hours of recorded lessons consisted of alphabet, common names and sentences, numbers, etc. The course was aimed at teaching a working and useful knowledge of Russian with no emphasis on grammar. At the end of the two months, he confessed that he was a pretty confused fellow on Russian and wondered just what would happen when he came face to face with Russian-speaking people. He was happily surprised, he said, that when the test came, he was able to fit words and phrases into their proper place and could carry on a very respectable conversation. Before the end of his eleven-weeks stay there, he was able to describe the Ampex Color Videotape Recorder in technical Russian language to Russian TV engineers. This technical description of the tape recorder is not easy even in English.

Mr. Roizen took with him a Leica M3 and a Bolex 16mm camera, with a Zoomar lens, and an ample supply of film which he used to photograph many things of interest in and around Moscow. Except for a special jet trip of 650 miles to Leningrad, Mr. Roizen, like all Americans, was limited to travel within a radius of 50 kilometers (31 miles) of Moscow. From the excellent pictures and interesting material, it was obvious that he made good use of his spare time while working at the American Exhibition. The excellence of the whole presentation indicated that Mr. Roizen was keenly interested in learning as much about the Russians as the time of his visit permitted and that he was able to bring back to our Society many fascinating things about the Russian people.—Carl W. Hauge, *Secretary-Treasurer*, c/o Consolidated Film Industries, 959 N. Seward, Hollywood 38.

The New York Section met December 10 at the World Affairs Center Auditorium, Carnegie Endowment Center, with an attendance of 35. J. S. Courtney-Pratt, Bell Telephone Laboratories, Murray Hill, N.J., addressed the group on "High-Speed Photography."

According to the speaker, it is possible to increase the rate at which pictures can be taken, by making use of the principles of image dissection. With this method, the picture is divided into a large number of small elements which may be lines or dots, and these are all recorded simultaneously on a photographic emulsion. The elements are spaced out so that (in at least one dimension) each is separated from its neighbors by a distance that is large compared with the width of the element. A second picture can be recorded by displacing the image with respect to the emulsion by the width of the image element rather than by the width of a frame, and this allows one to achieve the much higher recording rate. Image dissection cameras have been built that allow short series of good pictures at rates of 10^7 or 10^8 per second of remote objects and at or near unity magnification, or that allow cinematography at 10^6 pictures per second at magnifications up to 2000X. Alternatively, long series of, say, 10^8 pictures, of lower resolution are possible. Cameras to achieve these results use only inert optical elements and mechanical components. The use of the deflecting image converter in combination with dissection principles allows one to take short series of about 50 pictures of 100-line quality at rates approaching 10^9 per second.

An interesting discussion period was held after a social period. Edward M. Warnecke, *Secretary-Treasurer*, Eastman Kodak Company, 342 Madison Ave., New York.

The San Francisco Section met November 10 at KGO-TV Studios, San Francisco, with an attendance of 43. Speakers were Allan Atkins, W. A. Palmer Films, Inc.; Warren Zimmer, Pacific Productions; Bob Hovarka, Bob Mills and Milton Kerr, all of TV Cartoon Productions.

This meeting dealt with the "World of Animation." The first portion of it was devoted to the history of animation. A film made for this purpose by Walt Disney Productions was shown. This motion picture traced animation from the beginning to its present stage. Examples of various forms of animation, made by our guests, were shown also.

The second portion of the meeting was a round-table discussion. A panel comprised of experts in the field of animation answered questions from members.—Frank Mansfield, *Secretary-Treasurer*, 57 Stoneyford Avenue, San Francisco 24.

The San Francisco Section met December 8. The meeting was held jointly with the San Francisco Section of the I.R.E. A total of 133 were in attendance.

The main speaker of the evening was Joseph Roizen, Ampex Corp., whose subject was "Experiences in Russia With the American National Exhibition." Mr. Roizen told about how he spent more than two months in Russia with the Ampex Color Videotape Recorder display at the American National Exhibition at Sokolinski Park in Moscow. He told about the unusual opportunity of meeting and talking to many Russian people from every walk of life. Problems connected with getting the equipment into and out of Russia were brought up. 35mm color slides and 16mm color motion pictures were shown of the Exhibition along with scenes of Moscow and Leningrad.

An unusual stereotape recording of a Russian religious ceremony was played. A Videotape recording of the famous Nixon-Khrushchev debate was also shown and the story told of how the tape was taken out of Russia.

A display of various Russian goods, technical magazines, photo magazines, newspapers and postage stamps were on display for our members to examine after the meeting.—Frank Mansfield, *Secretary-Treasurer*, 57 Stoneyford Ave., San Francisco 24.

The University of Miami Student Chapter met on December 4. Charlton Heston, guest speaker, discussed motion-picture production abroad, including the particular problems that were involved in the production of *Ben Hur*.—Peter Hallinan, *Chairman*, University of Miami, Student Chapter.

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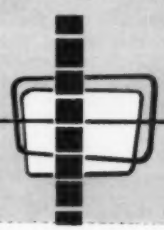

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Obituaries

John W. Boyle

John W. Boyle died September 29 following a long illness. A long and distinguished career as cinematographer began in 1913 in his home town of New Orleans, La., where he produced a newsreel known as the *Item Animated Weekly*. In 1915 he moved to Hollywood where he worked, as photographer, on the earliest motion-picture version of the *Queen of Sheba* and later on M-G-M's first production of *Ben Hur*. About 1940, he became interested in the uses of two-color cinematography and, with Benjamin Berg, published an account of his work in the February 1947 *SMPE Journal*, "Studio Production with Two-Color Bipack Motion-Picture Film." At that time, he was associated with Hal Roach Studios. An earlier paper, "Black and White Cinematography," was published in the *Journal* for August 1942. He was then with Universal Studios. A Fellow of the Society, for many years he was active in Society affairs, especially in the Pacific Coast Section. He was also an early member of the American Society of Cinematographers and was active in its management affairs. He was widely travelled and had filmed motion pictures in many foreign countries. During the Korean war he made a number of documentary films in the Pacific.

Melvin Karl Schleiter

Melvin Karl Schleiter, of St. Paul, Minn., died December 17, 1959, at the age of 54. He joined Reid Ray Film Industries in 1934 as a cameraman. During his 25 years as a cinematographer he travelled for his firm. He filmed a number of training films for various government agencies and was recently in charge of photography of classified films for an Army arsenal. He pioneered in early commercial color photography and was responsible for adapting lighting techniques to new color photography as the processes improved. He developed a number of mechanical improvements in motion-picture developing machines and camera attachments and a number of these devices are in current use by film producers. He was in charge of the photography of the State of Minnesota Centennial film, *An Agricultural Portrait*, which received a Certificate of Merit at the 1958 Venice Film Festival and was accepted for screening at the Brussels World Fair. A member of the Society, he was also a charter member of Local 666 I.A.T.S.E.

Joseph C. Gevaert

Joseph C. Gevaert, 59, died December 16, 1959, in Lausanne, Switzerland. Son of the founder of the international photographic firm, Gevaert Photo-Producten, N.V., Antwerp, he was President of the Gevaert Co. of America from 1933 to 1946. He served as Commissioner General of the Belgium Pavilion for the 1939-40 World's Fair. In 1958, he moved to Switzerland.

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Oliver Ellsworth Buckley

Oliver Ellsworth Buckley, retired Chairman of the Board of Bell Telephone Laboratories, died December 14, 1959, at the age of 72. He joined Bell Telephone Laboratories in 1925 and in 1927 was appointed Assistant Director of Research. Subsequently he was made Director of Research and then Executive Vice President. In 1940 he became President and in 1951 he was elected Chairman of the Board. His work on high-speed submarine telegraph cables achieved wide recognition, and research in various fields conducted under his direction included acoustics, electronics, photoelectricity, magnetism and microphonic effects. During World War II he served with the National Defense Research Committee and as advisor on technical problems to the War Production Board. He was awarded the Medal of Merit. He was a member of a number of organizations including the National Academy of Sciences and the American Institute of Electrical Engineers.

Will Whitmore, advertising manager in charge of sales promotion for the American Telephone and Telegraph Co., died October 20 at the age of 57. He was an active member of the Society during the 1920s and from 1927 to 1929 was an editorial staff writer on the *Motion Picture Herald.* In 1929 he joined the public relations department of Western Electric Co. and joined the AT&T staff in 1948.

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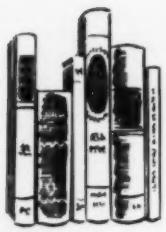

books reviewed

Eye, Film and Camera in Color Photography

By Ralph M. Evans. Published (1959) by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16. 9 by 5¾ in. i-xii + 410 pp. incl. index, table of contents, bibliography. Profusely illus., 16 pp. in color. Price $8.95.

A book by Ralph Evans is always a joy to read, and always an elucidation of some dark corners in the mysteries of vision and perception of color. The present work certainly runs true to this type.

The purpose of the book is to present an extremely generalized discussion of what the photographer really does when he takes a still or motion picture, particularly in color, and what the viewer really perceives when he looks at that picture. Probably the most important paragraph comes in the middle of the book:

"A basic underlying principle in aesthetics is that everything about a picture should aid the purpose of the picture. The final result should be a unity to which everything contributes in its own way. It is not likely that a photographer will produce such a result without a fairly clear-cut concept of what he is trying to do. At least we cannot say that a photograph is a good job from the photographer's point of view unless it succeeds, in part, in the direction he intended."

The author describes, in broad terms but also very carefully, the group of technical tools which the still or motion-picture photographer has at his disposal: the optical equipment, the mechanism of the camera, the properties of the film and photographic procedures, and the various methods available for the exhibition of his final pictures in projection or on sheets of paper. He describes in some detail the processes through which a viewer sees original subjects, and how he sees those subjects in reproduction. He indicates how the application and combination of these tools and effects enables the photographer to reach the objectives he set out to achieve.

A curious note is that the "perfect" photograph, each point of which exactly matches a corresponding point in the perspective view of the original scene in light (in the more general case, only proportional light), color and geometry, does not necessarily look like the subject. This is discouraging to the engineer, but differences in viewing conditions, visual adaptation, in information on the scene illumination, in specific information on

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An interesting and perhaps unusual feature of the book is the extent to which the author has considered the problems of the amateur:

"This group makes close to two billion single photographs each year and uses as much motion picture film as the whole professional industry.

"The casual photographer on the average knows nothing about photography and cares less. Any success he has with his pictures is due as much to the manufacturer's skill as to his own . . . .

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Not the least of the attractiveness of the volume comes from the lovely color illustrations by Miss Klute, which, as we have come to expect, are a joy to look at.

The engineer will occasionally wish that some of Mr. Evans' observations had been expressed more quantitatively. This would of course have lost part of the non-technical simplicity and smooth flow of his text. Such details can be looked up, with a little more effort, in the extensive bibliography he presents.

Summarizing, the work collects together the large body of phenomena that influence the quality of a viewed color reproduction. In certain cases these bring impairment and disappointment. The skilful photographer, however, foresees the operations of the phenomena and capitalizes on them or circumvents them.

The book will be most useful to all who deal seriously with pictures in one form or another.—*Pierre Mertz*, Lido Beach, L.I., N.Y.

TV and Film Production Data Book

By Ernest M. Pittaro. Published (1959) Morgan & Morgan, Inc., 101 Park Avenue, New York 17. 448 pp. incl. contents, index and adv., illus., diagrams, tables. 4 by 7 in. Price $6.95.

It can be honestly stated that this pocket-size book of 448 pages contains an amazing collection of up-to-the-minute data pertinent to the technical aspects of television and motion-picture production.

Brief descriptions by the manufacturers of five of the leading industrial and broadcast camera lines appear, together with descriptions of auxiliary equipment such as dollies, zoom lenses and monitors. Thirty pages are devoted to video-tape recording and splicing information, providing data for an elementary understanding of the recording and reproduction processes of this new technique. Motion-picture cameras, sound recorders, microphones, animation and lighting equipment are well represented, each with a brief description. Each of the major film manufacturers is represented with abbreviated

data for a wide variety of black-and-white and color films.

An assemblage of 45 tables, some of them developed specifically for this book, cover a wide assortment of data including 31 tables relating to lenses; six tables for conversion of 35mm and 16mm film to time, six tables for conversions between English to metric units of measure; one table for electrical current carrying capacity of wires; and one table relating shutter exposure time to various frame rates.

Of practical value, also, is the Manufacturers Directory, which contains addresses and phone numbers of 67 manufacturers of equipment pertinent to the field of television and motion-picture production.

It is obvious that this data book is an outgrowth of a rapidly evolving technology which blends the basically different equipment and techniques of motion pictures and television into a new era of moving image production. For those interested in either or both of these media, this book is a helpful and time saving guide.—*Ralph E. Lovell*, 2554 Prosser Ave., Los Angeles 64.

Perspective:

Quarterly Review of Progress in Photography, Cinematography, Sound and Image Recording. Vol. 1, No. 2, 1959

Edited by A. Kraszna-Krausz. Published by The Focal Press Ltd., 31 Fitzroy Sq., London, W.1.; and 303 W. 42 St., New York 36. 96 pp., 16 pp. illustrations, plus 6 pp. adv. 7¼ by 9¾-in. Price (subscription) $7.50.

The rapidly moving pattern of world events is approached in this publication from the standpoint of photography, cinematography and related fields. Issue number two continues to uphold the high level revealed in the first number and in some degree to surpass it.

About half of this issue is devoted to six short articles on various subjects. Two articles would seem to have special interest for the members of the SMPTE. L. A. Mannheim's review, "8mm in Search of Sound," describes the various methods and apparatus that have been devised for sound recording and reproduction in connection with 8mm film. European sound equipments for 8mm use are classified as follows: tape couplers and synchronizers; special tape couplers; striped film adapters; and striped film projectors. Members of the British Economist Intelligence Unit have written informatively on the "Tape Recorder Boom." They point out that there are about 125,000 tape recorders in use in Great Britain today (about 80% purchased by individuals) and that it is expected there will be about 180,000 sold by 1962. Much of the equipment is of German origin.

The remainder of this issue is devoted chiefly to 82 clearly written abstracts on research, products and methods. A few of the subjects covered are: Informational Sensitivity, The Photo-Electric Effect in Sensitizing Dyes, New Optical Glasses, Electronic Flash Exposure Meter, The Right Exposure at 20,000 f.p.s., Shadowgraph Missile Camera, Motion Picture Processing by Spray, High Speed Microfilm Selection, Cineradiography with Image Intensifiers, Mobile Television Studio, Televised Trucking, and New Life for Old Films.

Ten brief reports concerning market conditions in the United Kingdom, Italy, United States, and West Germany complete the issue. Reports by the Ilford and the Gevaert Companies include: Expansion by Independent Color Processors; Photographic Fair Trade in the U.S.; The French Optical Industry; and Import Changes in Pakistan, Cyprus and Canada.

Line or block diagrams are used throughout the volume to illustrate the text with the exception of the general article by H. W. Franke, "The Pictorial Idiom of Science." Here, 16 pages of halftone cuts reproduce many unique and beautiful patterns created in various ways by electrical and mechanical methods. Their use as a new art form or for creation of new patterns is suggested.

All in all, this interesting book well deserves the attention of the serious student of cinematography, television instrumentation or high-speed photography. —*Glenn E. Matthews*, Eastman Kodak Co., Research Laboratories, Rochester 4, N.Y.

Proceedings of the National Electronics Conference Vol. 14

Published (1959) by National Electronics Conference, Inc., 228 N. LaSalle St., Chicago Ill. i-xvi + 1074 pp. incl. numerous charts, diagrams and tables, + catalog of exhibitors xvii-xxi. 6 × 9-in. Price $7.50.

Growth is the order of the day for Electronics; the National Electronics Conference is no exception, coming forth each year with more exhibitors and more papers in more fields.

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this conference records the complete texts of all papers, technical and otherwise, given at the 1958 meeting. Some 80 of the papers are concerned directly with technical subjects, ranging from audio and television to servo mechanisms and transistors. In total, 17 technical specialties receive treatment. A large number of papers deal with the allied topics of engineering education, writing and speech, and engineering management, while four papers discuss results of space probes and other studies during the International Geophysical Year. Three historical papers complete the *Proceedings*.

The Audio and Television fields fare quite well; three papers deal directly with television design problems:

"Design Considerations in the Second Detector Circuit of Monochrome TV Receivers" by L. J. Mattingly

"The Optimum Source Impedance and Noise Figures of TV Input Tubes With Various Circuits" by L. E. Matthews

"Automatic Hue and Amplitude Control in Color TV" by Z. Wiencek

In the audio field, two articles are concerned with audio-frequency power amplifier performance, and "A Two-Way Stereophonic Amplifier" by Bauer, Hollywood and Markle describes a unique single channel amplifier used to amplify independently the left and right stereophonic signals. The two-way amplifier provides economy over two separate amplifiers of similar performance and equal total power. Other papers of possible interest to the TV engineer discuss the applications of lumisters and electroluminescent devices as display elements.

The vast scope of the material covered makes it obvious that no subject can be covered in any great detail, and that any listing of categories is, perforce, sketchy. The *Proceedings* do, however, present a fairly complete picture of the present state of the Electronic Art, and may be used as a good source of current information on many topics. The papers are well written and lucid, and indicate an excellent editing job. In addition, the typography is good, the type size being generous enough to favor tired old eyes.—*M. T. Pappas*, General Precision Laboratory Inc., Pleasantville, N.Y.

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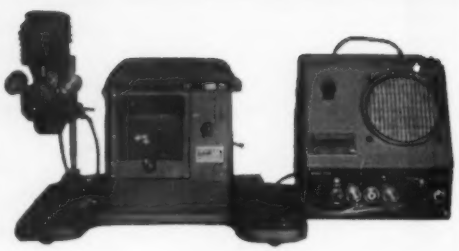

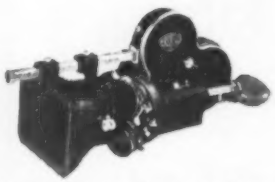

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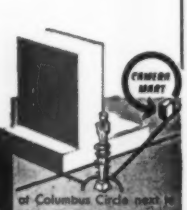

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Camera, July 1959, 38th year, No. 7, Official Organ of the International Federation of Photographic Art, published by C. J. Bucher Ltd., Lucerne, Switz. English-Language edition U.S.A. Distributor, Eastern News Company, 306 W. 11 St., New York 14, 88 pp., numerous illus., $1.00.

This special issue devoted to aerial photography is such a magnificent publishing achievement that it should not be overlooked. The reproductions, in both monochrome and color, comprise an unusual collection.

The first of a baker's dozen items on the camera in the air is "Various Aspects of Aerial Photography With Manhattan as an Example," a collection of seven pictures taken at a variety of heights and angles by Fairchild Aerial Surveys Inc. and the U.S. Coast & Geodetic Survey. One folded-in composite of ten vertical photographs is 51½ by 10⅝ in. The area embraced stretches from the southern tip of Governor's Island to about 115th Street in Manhattan. Automobiles and trees may be counted in the reproduction. The picture was taken with the 9 by 9-in. fully automatic Wild RC5A series camera with *f*/6 Wild-Aviogon wide-angle lens at a height of 7570 ft, and is reproduced in a scale of 1 : 15,000.

An article on the use of aerial photography in taking a census of African game is illustrated in black-and-white, plus a beautiful color page showing a herd of gnus on the run in Tanganyika. Animals were trapped, marked, and released, and their pictures from the air were used to trace their migrations as well as to determine their numbers.

In "Photography and Archaeological Exploration," Prof. Carle M. Lerici of Rome reports, with illustrations, on the application of hypoperiscopic photography (photographic probing) to underground areas prior to excavation. The Minox camera, built into a cylinder 60mm in diameter, produces 8 by 11-mm negatives in cassettes of 50 exposures. The use of aerial photographs to detect sites that should be excavated is also described.

A 2-page color spread showing the Island of Batz, near Le Croisic, France, a second color plate and many black-and-white photographs illustrate a discussion of aerial photography in map making and

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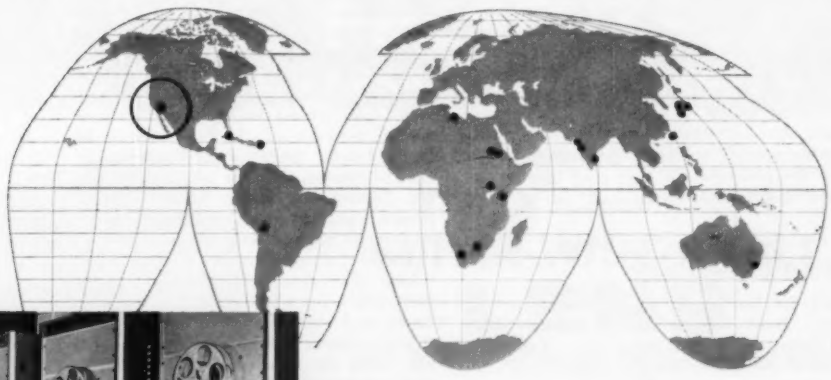

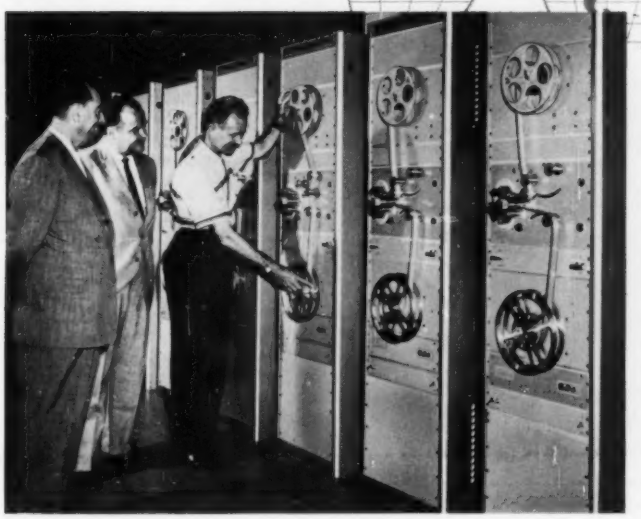

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topographical surveying. Two simplified projections of the globe show the cartographical coverage by photography achieved by 1953, when more than half the earth's land surfaces had been recorded on film.

By no stretch of the imagination can this be called a technical publication, but the July 1959 *Camera* is a technical achievement in which every professional in the photographic field may take pride and find pleasure.

Film: An Anthology

Ed. by Daniel Talbot. Published (1959) by Simon and Schuster, Rockefeller Center, 630 Fifth Ave., New York 20. xiv + 649 pp., 6¼ by 9¼-in, Price $8.50.

Film: An Anthology, described on the jacket as "a diverse collection of outstanding writing on various aspects of the film published from 1923 to 1957," parts the curtains on a "3-D" picture of the art for which the motion-picture engineer provides the materials. The three dimensions that Daniel Talbot suggests are: I, Aesthetics, Society Commentary and Analysis; II, Theory and Technique; and III, History and Personal.

The first section offers "critical appreciations and evaluations of the film as an art form and a social instrument" by such diverse writers as Elie Faure, Erwin Panofsky, Allardyce Nicoll, James Agee, Manny Farber and Gilbert Seldes, among others. Section II samples discussions of the techniques of the film art by some of its greatest practitioners — Pudovkin, Béla Balázs, Eisenstein, Rene Clair, Jean Cocteau and Paul Rotha — and adds some passages from Rudolph Arnheim's *Film as Art*. Section III opens with "First Night on Broadway," from Terry Ramsaye's *A Million and One Nights*, and includes verbal portraits of D. W. Griffith, by Lewis Jacobs; and Samuel Goldwyn, by Alva Johnston. Aspects of "moviedom" are discussed by Henry Miller, Leo C. Rosten, Lillian Ross and Ben Hecht; and several other writers are represented.

Daniel Talbot, who was Eastern Story Editor of Warner Brothers Pictures for three years, has selected well from a wide range, and makes available several essays that are classics in the field. For those without either the time or the inclination to read the complete works from which these pieces are taken, this book provides a good "short course." There are some obvious omissions, such as Raymond Spottiswoode, but two of his books are listed in the well-annotated bibliography. Notes on the contributors and an adequate index round out the volume.

The Engineering College Research Review 1959 (Ninth Edition) is edited by Renato Contini, Secretary, Engineering College Research Council, New York University, and Paul T. Bryant, Editor, *Journal of Engineering Education*, University of Illinois. It is published by the Engineering College Research Council of the American Society for Engineering Education. The 459-page volume contains complete titles for all projects underway in schools which hold ECRC membership. Research personnel at each institution are listed and research policies are summarized. The book contains a complete index of research project subjects to help locate activities in similar fields at different institutions. According to the *Review*, more than 10,000 research projects are now underway in 118 engineering colleges in the United States. Budgets for these research activities for the current year total more than $112 million.

Printed Circuit Diagnosis Made Easy, by C. P. Oliphant, is a 64-page book published by Howard W. Sams & Co., 1720 E. 38 St., Indianapolis 6. The book is intended primarily as a guide to service technicians in the servicing of printed circuits in television and radio chassis. It is priced at $1.00 and is available from bookstores and electronic parts distributors.

Electronic Switching, Timing and Pulse Circuits by Joseph M. Pettit is published by McGraw-Hill Book Co., Inc., 330 West 42 St., New York 36. The book offers a basic type of analysis for circuits in which tubes or transistors are used primarily as switches having nonsinusoidal waveforms. The author is Dean of Engineering and Professor of Electrical Engineering at Stanford University.

The Changing Picture in Video-Tape for 1959–1960: A Review for the Television Industry (2d ed.), a Minnesota Mining and Mfg. Co. publication (61 pp., illus.) is a readable collection of quotations from about 40 trade and scientific magazines, interviews and papers on the subject of video tape. It contains a number of simplified statistics and items of information. Video-taped TV programs are described in detail and techniques of writing, producing and directing are discussed. The book is priced at $1.50. It is available from the publishers by addressing P.O. Box 3500, St. Paul, Minn.

Visual Aids in Fundamental Education and Community Development by Romash Thapar is No. 27 in a series of reports and papers on the subject of mass communication published by Unesco. This report is on a regional seminar in South and South East Asia held in New-Delhi, India, in September 1958. Topics discussed included theoretical aspects of the production and use of visual aids in fundamental education; practical aspects of the production and use of visual materials; professional training of technicians and educators in the production and use of visual materials; supply and distribution of visual material and equipment, and the use of visual aids in literacy teaching for adults, teaching and writing in the mother tongue, and teaching a second language to persons illiterate in their own. Report No. 27 is available from National Distributors of Unesco Publications or from Mass Communication Clearing House, Unesco, Place de Fontenoy, Paris 7e, France. It is priced at 75 cents.

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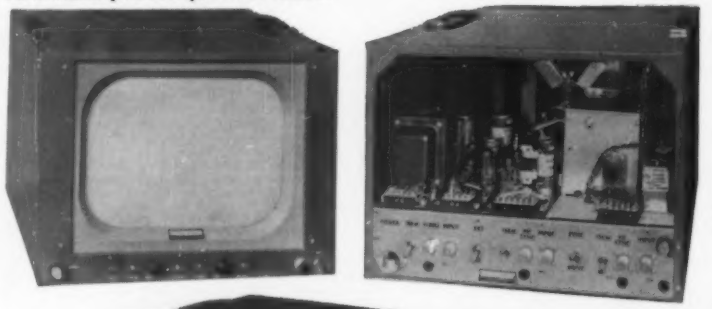

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Lip-synch recording with ¼" tape

The most desired portable professional motion picture camera in the field achieves a new dimension... new production versatility...with this Synchronous Signal Generator. (Illustrated on Arriflex 16—similar installation also available for Arriflex 35.)

Standard battery operates the governor-controlled DC motor on the Arriflex—**no need for generators or invertors to supply AC.** As camera runs, the Synchronous Signal Generator produces a 60-cycle current, which is fed to a special recording head mounted on a tape recorder. This puts a control signal on ¼-inch tape at approximately 90 degrees to the audio signal. In re-recording to film—magnetic or optical—this control track is amplified and controls speed of playback, maintaining frame-by-frame synchronization.

This unit can be installed on all Arriflex models.

*Licensed by and compatible with "Rangertone," Newark, N. J.

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for **extreme wide-angle** filming...

TEGEA 5.7mm f/1.8/T2

SUPER-WIDE-ANGLE LENS

with **built-in filter slot for 2" square filters**

and **special lens shade.**

This remarkable retrofocus super-wide lens extends the scope of Arriflex filming for such applications as instrumentation, architecture and interiors, and for special effects. While extreme-wide-angle lenses present finder problems with conventional cameras, the Arriflex, because of its famous mirror-reflex system, is **ideally suited** to the 5.7mm Tegea.

OPTICAL SPECIFICATIONS: Bench-tested and selected according to critical ARRI tolerances. Unusually even coverage of the field in spite of extremely short focal length. Distortion corrected to 1.7° for field of 100°. Superb definition over the entire 16mm frame. Angular field 113°.

DEPTH OF FIELD TABLE based on circle of confusion of .025mm (1/1000")

Diaphragm setting	Sharp from	To
1.9	19"	infinity
2.8	16"	"
4	14"	"
5.6	12"	"
8	10"	"
11	9"	"
16	8½"	"

APPROXIMATE MECHANICAL SPECIFICATIONS
Overall length beyond lens mount; 4½"; with lens shade; 6"
Front diameter of lens; 3½"
Weight of lens without lens shade; 30 oz.; with shade; 36 oz.
Front dimension of lens shade; 4x6"

ARRIFLEX CORPORATION OF AMERICA
257 PARK AVENUE SOUTH, NEW YORK 10, N. Y.

Nontheatrical Films — An Interim Report

By JOHN FLORY
and THOMAS W. HOPE

This Report supplements and brings up to date the authors' exhaustive study of the nontheatrical field, "Scope and Nature of Nontheatrical Films in the United States," published in the June 1959 issue of the Journal *(pp. 387–392).*

Spending for nontheatrical films and visual communication tools reached an all-time high in 1959 with an estimated total of $287 million — $32 million over the 1958 total of $255 million.

The greatest percentage gains were from film activities in medicine, business and industry, education and civic and social welfare agencies. Smaller gains were in religion and government buying.

The increases in medicine and business were caused in part by a decided trend toward low-cost film production and film circulation (distribution). Education had an increase in classroom film production in addition to greater all-around audio-visual activity and buying.

Nontheatrical motion-picture production with its related release-print volume and film distribution made a sizable increase. These three segments accounted for 72% of the total money spent for visual communications. The production of filmstrips, 2 x 2 color slides, and overhead transparencies made good gains in 1959.

The comparatively modest increase in the equipment figure is accounted for by a delayed reaction to the National Defense Education Act of 1958. After Congress passed the law, some months elapsed before the U.S. Office of Education and the various States could set up regulations and machinery to implement the program of stimulating more and better teaching of sciences, mathematics, modern foreign languages, and area studies by means of more effective use of audio-visual methods. Meanwhile, schools held off their buying in the first half of 1959. Sales in the third and fourth quarters of the year were far in excess of sales during the first half of the year, according to reports from equipment manufacturers and educational film producers. The year-end buying brought the equipment sales figure for 1959 to a 7% gain over 1958.

Nontheatrical motion-picture productions completed during the year jumped 16%, from 7300 in 1958 to approximately 8440 in 1959. Films for medicine and health made a spectacular gain of 33% while business and education productions were up a healthy 20%.

Employment increased slightly in 1959. The total number of persons working full time in the visual communications field at the end of 1959 probably is close to 48,000.

Sales of 16mm motion-picture sound projectors reached an estimated total of 36,000 in 1959, bringing the total number of machines in the United States to about 632,500.

This report has been prepared by John Flory, Advisor on Nontheatrical Films, and Thomas W. Hope, Assistant Advisor, Eastman Kodak Co., 343 State St., Rochester 4, N.Y.

Table I. Who Spends the Money? Estimated Nontheatrical Film and Audio-Visual Expenditures in the United States by Type of Purchaser* (in millions).

	1957	1958	1959	1959 vs 1958
Business and Industry	$156	$150	$171	+14%
Government (Federal, State, Local)	49	48	51	+ 6%
Education	25	27	32	+19%
Religion	14	15	16	+ 7%
Civic, Social Welfare, etc.	7	8	9	+12%
Medicine and Health	6	7	8	+14%
Totals	$257	$255	$287	+12%

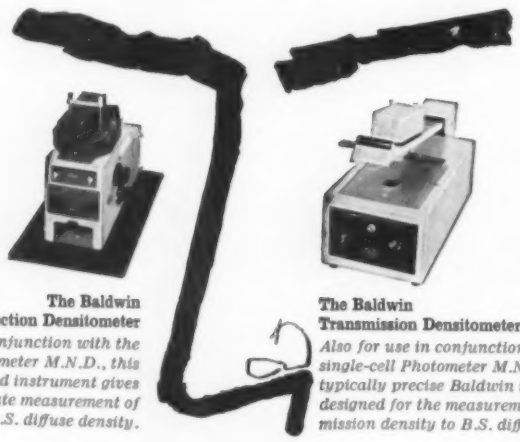
* Includes films, equipment, and other audio-visual materials, but does not include tape recorders and other audio-only equipment and materials.

Table II. How Is the Money Spent? Estimated Nontheatrical Film and Audio-Visual Expenditures by Type of Product (in millions).

	1958	1959	Percentage Change
Production (Motion Pictures)	$ 95	$107	+13%
Release Prints	49	57	+16
Distribution	38	42	+12
Equipment	29	32	+ 7
Other Audio-Visual	44	49	+12
Totals	$255	$287	+12%

Table III. Estimated Number of U.S. Nontheatrical Film Productions.

	1958	1959	Percentage Change
Business and Industry	4,500	5,400	+20
Government (Federal, State, Local)	1,500	1,500	no change
Education	500	600	+20
Medicine and Health	300	400	+33
Religion	200	220	+10
Civic, Social Welfare, etc.	200	210	+ 5
Experimental & Avant Garde	100	110	+10
Totals	7,300	8,440	+16%



The Baldwin Reflection Densitometer
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The Baldwin Transmission Densitometer
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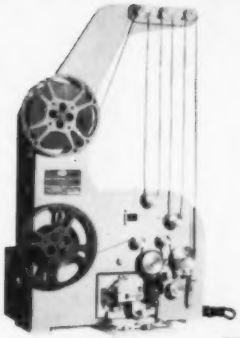
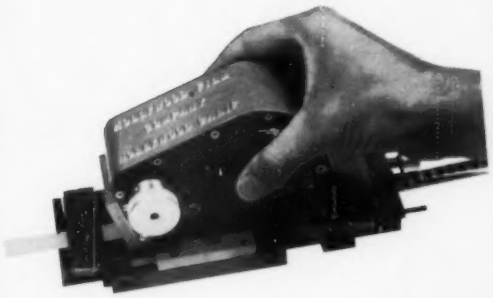


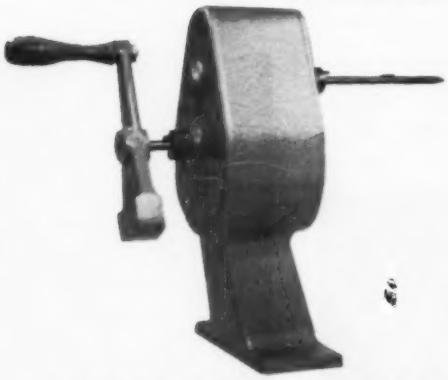
EDGE NUMBERING MACHINES

NEGATIVE BREAKDOWN REWIND



AUTOMATIC SPLICERS

HOT SPLICERS



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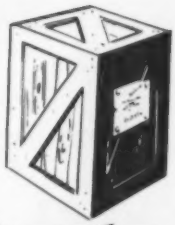


new products

(and developments)

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products or services.

Thermoplastic Recording

An electronic process for recording, storing and reproducing photographic images and technical data on thermoplastic film is described in an article by W. E. Glenn, published in the December 1959 issue of the *Journal of Applied Physics*. Dr. Glenn, a scientist with General Electric Research Laboratory, did not, in the article, suggest possible applications for the new process, but the potentialities of the discovery have changed the thinking, in many areas, of motion-picture and television industrialists and its impact is presently reflected in the stock market. Other than motion-picture and television uses, applications that have been discussed by interested observers include electronic computers, data storage and space and missile research. Howard A. Chinn, Chief Engineer of CBS, in an interview reported in the *New York Times*, Dec. 24, 1959, commented on the advantages of such a process (thermoplastic recordings can be played back instantaneously and erased and reused like video tape and have visible images like film) and suggested that thermoplastic recordings may, in the future, be largely substituted for both film and video tape. William Lodge, Engineering Vice-President of CBS, quoted in the *Television Digest* of January 4, commented that development of a working method of thermoplastic recording will take a long time. Frank Marx, Engineering Vice-President of ABC also expressed a "wait and see" attitude. George I. Long, President of Ampex, said that he believed that the "major application will be as an adjunct to existing recording magnetic techniques rather than as a replacement."

The process is based on use of an electron beam to cause "deformations" on the surface of a thermoplastic film. The deformations can be detected optically, and images can be projected from the film by means of a special optical system. First step in the process is the conversion electronically of technical data or photographic images into coded signals. The signals are further reduced to variations in the intensity of a beam of electrons. The electron beam is then directed back and forth across a three-layer film. The positively-charged middle layer is sandwiched between a layer of heat-resisting plastic and a top layer of thermoplastic film with a relatively low melting point. When the electron beam moves across the thermoplas-

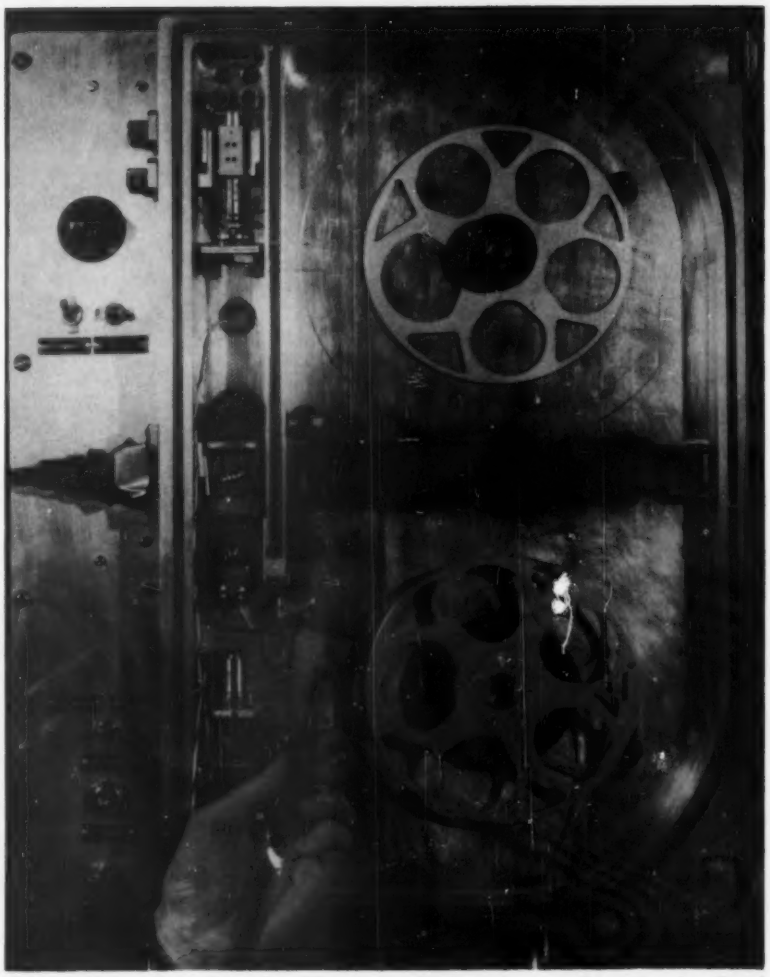


Fig. 1. Thermoplastic Recorder. The thermoplastic tape moves from the playoff reel (bottom), past an electron gun, a heating unit, and an optical monitor to the take-up reel (top).

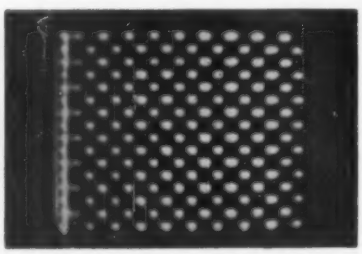


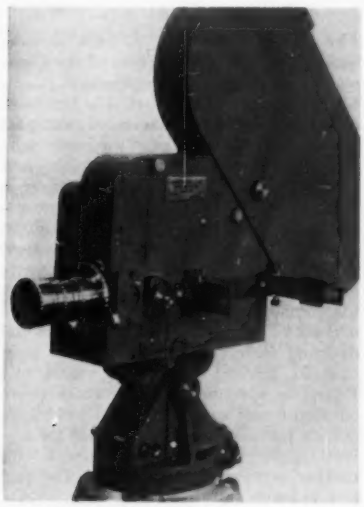
Fig. 2. A suggested application for thermoplastic recording is data recording and storage. A "checkerboard" pattern recorded on thermoplastic tape is approximately $\frac{3}{1000}$ in. in length and width. With the binary digit system, where the light and dark squares could represent 0 and 1, it would be possible to record at the rate of 40 million bits per square inch of thermoplastic.

Fig. 3. Each frame of the thermoplastic record, above, is less than $\frac{1}{4}$ in. wide and fits easily inside a paper clip. The image is recorded in the form of microscopic indentations, but when ordinary light strikes the record at an angle, the image can be seen with the naked eye.

tic film, a pattern of negative charges is deposited on the film in accordance with the data or images to be recorded. The next step is the conversion of this pattern to a pattern of depressions and ridges by means of a heating unit powered by radio-frequency energy. The heat melts the top, negatively charged layer of the film, causing the deposits of negative charge to be attracted to the positive charge beneath, effecting a pattern of "ripples" — or deformations — on the surface of the film. Next, a beam of light is passed through the film and into an optical system which makes it possible for the image to be viewed directly, projected onto a screen, transmitted electronically for TV viewing, or stored on the film. The pictures can be projected in black-and-white or color.

Dr. Glenn, in this paper, did not refer directly to any similarities between the process he described and the Eidophor process, but an apparent relationship between the principles of thermoplastic recording and the "ridges and valleys" of the Eidophor projector has been noted by some commentators. The Eidophor projector employs electronically produced wrinkles on an oily surface to produce a TV picture, while the "ripples and ridges" of thermoplastic recording are deposited electronically on film for a more permanent record.

Following publication of the article, Ampex Corp. issued an announcement stating that the firm "has had under study for several years the process of recording sight, sound and coded impulses on thermoplastic film by means of an electron beam." The announcement (issued Dec. 28, 1959) also states, "this and other promising new recording methods were described in a widely circulated Ampex bulletin issued in September 1959."



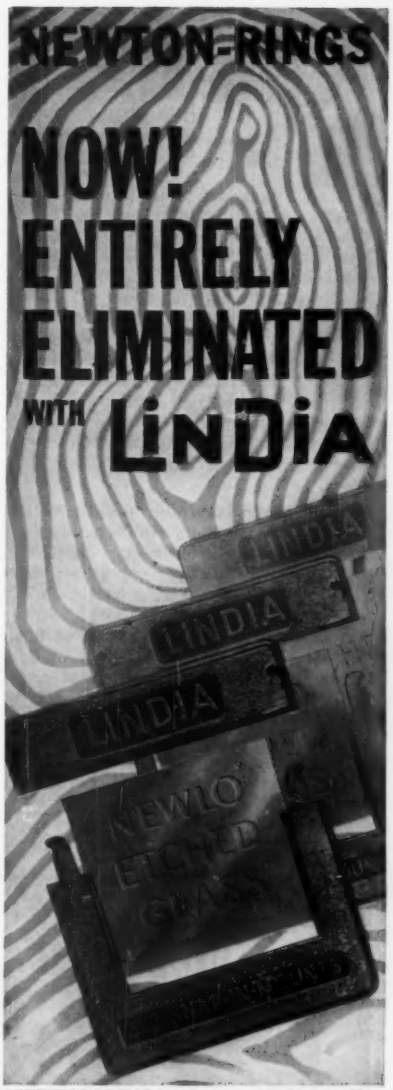
The Waddell Camera, a 16mm high-speed motion-picture camera designed by John Waddell, has been announced by Camera Equipment Co., 315 W. 43 St., New York 36. The new camera has a speed range of from 3 to 10,000 pictures per second, depending on the camera model and motor combination. It will accept the normal 400-ft magazine, and is driven by either a permanent magnet 26-v d-c or a 115-v a-c/d-c, depending on the model. Features include electronic flash synchronization and exposure playback for oscillograph recorders; variable height fixed aperture plate; two built-in NE2H timing lights; manual or remote camera operation; film cutoff switch which operates an independent 20-amp load relay; boresight focusing; all components designed to withstand high G. The camera weighs 35 lb and measures 8 in. by 7 in. by 7 in. Available accessories include a complete series of lenses from 3.2mm to 152mm. All lenses include standard series filters. Also available are 1 to 10 miniscus close-up lenses; optical relay fiducial marker; and synchronizers. Depending on the model, the price is from $1775.00 to $1850.

A Catadioptric Light Screen which sets up a plane of light sensitive to hypervelocity projectiles from .22 caliber and up has been developed by Avco Research and Advanced Development Div., Wilmington, Mass. The device sets up a stream of light consisting of a collimated light beam which is reflected many times between parallel mirrors before passing into a photoelectric detector. A current change is caused in the detector when a hypervelocity projectile breaks the light screen at any point. The current change is amplified and is used to trigger a shadowgraph system. The light screen measures 9½ in. high by 10 in. wide by 6½ in. deep. It has a uniformly sensitive screen area 6 by 6 in.

The Model 335 Stand, developed initially for use with the Magnifax High-Speed Motion-Picture Camera is a product of Beckman & Whitley, Inc., 973 E. San Carlos Ave., San Carlos, Calif. The stand weighs 43 lb, stands 61 in. high and provides camera-platform adjustments from 14 in. to 62 in. above floor level. Recommended for use with instruments weighing between 20 and 40 lb, features include a metal ring at the base of the stand through which camera cables can be passed to minimize the possibility of tipping the stand by an accidental pull.

The Oscar Model K, an oscillogram and strip chart record reader designed for small laboratories and test facilities, has been announced by Benson-Lehner Corp., 1860 Franklin St., Santa Monica, Calif. The reader measures trace amplitudes, applies a linear or nonlinear calibration, converts the data to engineering units and automatically operates a typewriter and punch card.

The Sens-OAR-chrome is an electronic color monitor and control unit for displaying information revealing variations in hue and in intensity of light received from test samples. A product of Comapco Inc., Suite 207, 17071 Ventura Blvd., Encino, Calif., the initial model (1B1) is intended primarily for analysis and control of light transmitted by liquids, sols, gels, or solid transparent or translucent objects. The basic photocell system is designed to have a pattern of color-sensitivity resembling that of the human eye.



NEWTON-RINGS, those optical gremlins that thwart all efforts at *color-perfect slide projection,* can now be a thing of the past. LINDIA'S Swiss made "NEWLO" glass, with special *etched surface,* completely *eliminates* this disturbing rainbow phenomenon. By providing for the *free flow of air* between film and protective glass, *etched* surfaces *prevent all* moisture condensation . . . VOILA — NO NEWTON-RINGS!

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A miniature incandescent lamp described as "the smallest ever produced on an assembly line," has been announced by Sylvania Electric Products Inc., 730 Third Ave., New York 17. The lamp, called the Mite-T-Lite, is cylindrical with a diameter of approximately 0.040 in. Its length is about 0.125 in. The lamp leads are platinum in a diameter of 0.005 in. The filament is 0.00025-in. tungsten wire of approximately 30 turns. Suggested applications include airborne electronic systems, high-speed punch-card and readout devices, compact matrix displays, photoelectric logic systems and other microminiature circuits.

Automatic exposure and processing of photographic plates used in the permanent memory of an experimental electronic telephone switching system, called the Flying Spot Store, is a development of Bell Telephone Laboratories. The information is in the form of thousands of tiny clear dots on an otherwise opaque photographic area two inches square. Seventeen areas are used together to make up a complete photographic plate, and the entire permanent memory store is made up of four such plates. The spots of clear and opaque film are scanned by a beam which is generated by a cathode-ray tube and focused by a system of lenses. The movement of the beam is controlled by an electronic and optical positioning system. The plates are exposed when the moving beam from the cathode-ray tube is focused through an objective lens onto the photosensitive area. The spot is moved over the entire two-inch-square image area and stopped briefly at positions where a spot exposure is desired. After exposure the plates are placed in an automatic processor for developing and fixing. The Flying Spot Store and the automatic processor are described in papers which were presented at the recent meeting of the Society of Photographic Scientists and Engineers in Chicago, by M. B. Purvis and G. V. Deverall; and by R. K. Eisenhart and R. F. Glore.

An experimental device that reads handwritten words has been built at Bell Telephone Laboratories. It has a ten-word vocabulary, "zero" through "nine" spelled out. To use the reader, the writer moves a metal stylus over a special surface just as if he were writing with a pen or pencil. The stylus is wired to make electrical contact with 15 horizontal metal strips alternately sandwiched between strips of electrical insulating material on the surface. Up-and-down movements of the writing cause electrical connections to be made with the metal strips in sequence. The sequence and number of connections tell the device which of the ten words has been written. When the writer touches an "Identify" button with the stylus a light appears beside the numeral corresponding to the word he has written. This device is believed to be the first to read cursive script despite variations in individual style. It also explores machine reading by entire words rather than letter by letter.

Catalog H, a new 54-page catalog has been issued by Mole-Richardson Co., 937 N. Sycamore Ave., Hollywood 38. The illustrated volume gives descriptions and specifications for lighting equipment, pedestals, grip equipment, special effects equipment, microphone booms, power distributions components and also contains a revised 8-page list of books which the firm stocks.

Three new ColorTran lighting units, products of Natural Lighting Corp., 630 S. Flower St., Burbank, Calif., are described in a folder available from Camera Equipment Co., 315 W. 43 St., New York 36. The new lighting units are Cine King Light for spot or floodlighting, designed for use with the Par 56 (300-w) sealed-beam aircraft-type lamp, or the 500-w Par 64; the Super Kicker used to boost power lighting in close-ups and the Kicker, a slightly smaller version of the Super Kicker.

A method of connecting wires and component leads without soldering has been developed by Plastic Associates, 185 Mountain Rd., Laguna Beach, Calif. The junction cell consists of a gold-plated eyelet and a rubber core. When the core is pulled upward the rubber stretches allowing wires to be slipped easily inside the eyelet. When released, the rubber core grips the wires or component leads, pressing them firmly against the gold-plated surface and establishing an electrical contact of essentially zero resistance.

The National Carbon Co. field service, which is part of the program of the Company, a Division of Union Carbide Corp., 535 Fifth Ave., New York 17, has been advanced by the issuance of compact service kits to the 12 sales engineers who work directly with projectionists and theater owners on screen lighting problems. Each kit contains the following equipment: brightness meter to measure footlamberts on the screen; foot-candle meter to measure incident light on the screen; volt-ohmmeter and clamp-on ammeter for checking electrical conditions at the lamp; dummy lens and set of alignment rods and accessories designed for every carbon size and lamp now in service; pinhole apertures and split-plate aperture plates for quick check on alignment; stop watch for checking on carbon burning rate; micrometer for carbon measurements, and sliderule for making accurate calculations in the projection booth.

Wilding Inc., a Chicago firm specializing in industrial motion pictures and sales promotion, has announced the purchase of Commercial Pictures Equipment, Inc., manufacturer of specialized equipment for industrial motion-picture and slidefilm projection. A. J. Bradford, who founded the latter firm, will remain as its president.

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A new branch of Camera Equipment Co., called CECO of Florida, has been opened at 1335 E. 10th Ave., Hialeah, Fla. The new branch will carry a full range of professional equipment and will maintain a repair and service department. It is conveniently located to downtown Miami and Miami Beach.

Camera Equipment Co., 315 W. 43 St., New York 36, has been appointed agent for TelePrompTer in the motion-picture field. The service is available at a price of $125.00 for an eight-hour day. Installation and operation is by TelePrompTer-trained personnel.

Establishment of a Closed-Circuit Television Division has been announced by Marconi Wireless Telegraph Co. Purpose of the new division is to coordinate and expand activities in the military, scientific, industrial, commercial and educational applications of closed-circuit television. Changes made in the Broadcasting Division as a result of the formation of the new Division include the appointment of G. E. Partington as Chief Engineer of the Broadcasting Division.

The Federal Machine Tool Co. of Boston has been purchased by Houston Fearless Corp. for an undisclosed amount of common stock. The company will retain the Federal name and will operate as a division of Houston Fearless. Major activities include precision tooling and design and the manufacture of electronic components and automated chemical process control equipment.

Houston Fearless Corp. has moved its New York Regional Office and Showrooms to General Motors Building, 1775 Broadway, New York 19. The head office and plant are in Los Angeles.

Vicom, Inc., 800 Linden Ave., Rochester 10, N.Y., is a new firm specializing in the field of motion-picture equipment, magnetic film recording systems, audio-visual systems and optical projection systems. Announcement was made by Fred E. Aufhauser, head of the new company. He was formerly President of Projection Optics Co., Rochester, N.Y.

Video Talk, Bulletin No. 1, is the first of monthly series on the use of video tape to be issued by Minnesota Mining and Mfg. Co., Magnetic Products Advertising, 900 Bush Ave., St. Paul 6, Minn. This first bulletin, available upon request, is accompanied by a folder for permanent file purposes and specification pages for tape and tape reels.

The 1960 (24th) edition of the *Radio-Electronic Master* published by United Catalog Publishers, Inc., 60 Madison Ave., Hempstead, N.Y., provides detailed descriptions, specifications and prices of more than 170,000 standard stock items sold through electronic distributors. Products of 330 manufacturers are listed in the 1551-page catalog, which contains more than 12,500 illustrations. The volume may be obtained from local electronic distributors throughout the United States and Canada.

Model 70A, a closed-circuit TV camera designed for heavy-duty industrial use as well as general closed-circuit applications, has been developed by Dage Television Division, Thompson Ramo Wooldridge Inc., Michigan City, Ind. The camera features a newly-developed transistorized video amplifier which eliminates microphonics and provides 600-line resolution. Electronic circuits automatically make instantaneous adjustments to variations in light levels. Other features include on-chassis controls to regulate horizontal and vertical size, linearity and centering, and adjustments for beam and black level. The camera is $7\frac{5}{8}$ in. high, $5\frac{1}{16}$ in. wide and $11\frac{13}{16}$ in. long. It operates on 45 w, 115-v, 6-c power. It is priced under $1400.

Selector Charts designed to make it easy to select the proper compound, coating, foam or bonding agent suitable for specific requirements are contained in a bulletin (Bulletin 121) available from Plastic Associates, 185 Mountain Rd., Laguna Beach, Calif. Definitions are provided for such terms as casting, encapsulation, impregnation, and coating. The charts offer hard, semi-rigid and flexible formulations for each processing application.

A 16mm projector with a specially designed 15-w amplifier has been announced by Victor Animatograph Corp., Div. of Kalart, Plainsville, Conn. Called the Kalart/Victor Model 7–15, it is designed for quietness of operation, ease of maintenance and flexibility. An 8-in. speaker, an integral part of the projector door, may be operated on the projector or may be detached and placed anywhere up to 50 ft away from the projector.

A closed-circuit TV system supplements the stock quotation board of a New York brokerage firm to make latest price information available to employees and customers in widely separated locations. Designed by General Precision Laboratory Inc., Pleasantville, N. Y., the system consists of a TV camera which feeds pictures of the ticker tapes to 15 monitors placed in offices, research and sales areas. The system employs a device described as a "dual 'damping' device" to transmit clear images of prices. A standby camera can be brought into use by means of a switch-over panel.

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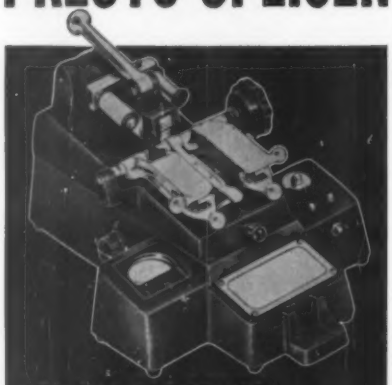

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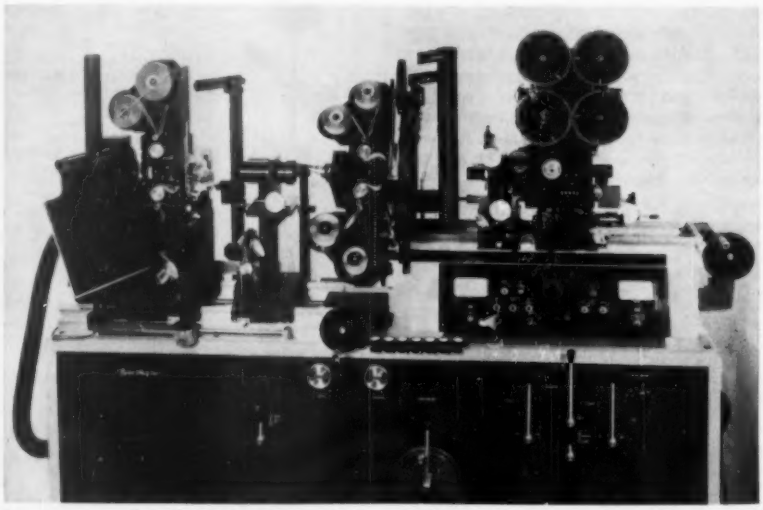
An optical fiber probe linked to a closed-circuit TV system for use in dental and medical instruction is under development by Avco Research and Advanced Development Division, 201 Lowell St., Wilmington, Mass. The probe system consists of a bundle of optical fibers bound together in a small whip-like cable with a fingertip-size lens arrangement at the probing end and coupled to a closed-circuit TV camera at the other end. A bundle contains up to 10,000 of the hair-like fibers. Each fiber picks up light from a microscopic section of the surface in front of it and transmits the speck of light to the other end. With thousands of the fibers bound tightly into a cable, a picture made up of the thousands of light segments can be sent from a lens placed, for example, inside a patient's mouth for dentistry instruction, to the TV camera and from there to the screen, where a tooth or a portion of it can be seen magnified up to 35 times its actual size.

A demonstration of the interchangeability of color TV tape recordings on machines manufactured by the same firm was conducted by the RCA Broadcast and Television Equipment Division on October 27 at Camden, N. J. The new RCA Color TV Tape Recorders have been designed so that a color tape made on one RCA machine can be played on another RCA machine with a different head assembly. Electrical and mechanical precision in the manufacture of the head wheel assembly is the basis for the interchangeability feature.

Purchase of a $½ million mobile color TV tape recording studio by Red Skelton has been announced jointly by Ampex Corp. and General Electric Co. The studio-on-wheels will be contained in two vans and a truck carrying an auxiliary power unit. Equipment includes two Ampex VR-1000B Videotape color television recorders; waveform monitors (Tektronix 525); video monitors (Conrac CM 17/R); audio monitors (Ampex 9901); color monitor (Conrac CH 21 B); tape splicer kit and audio and video patch panel with distribution amplifier. The color camera to be used is the G.E. Type PE 15A. The switching panels are GE Type TS 2A. The transistorized audio console is GE Type BC21A.

The Mark VI-M, a manually controlled version of the remote controlled Mark VI zoom lens for vidicon cameras, has been introduced by Zoomar, Inc., Glen Cove, L.I. The lens has a zoom range of 6:1 and a focusing range of 8 in. to infinity. The speed and focal length ranges are: *f*/3.5, 25mm to 150mm; with optional extender, *f*/5.6, 40mm to 210mm. The resolution is 800 TV lines. The coverage is ⅝ in. diagonal. Dimensions are 2½ by 2½ by 6½ in. and the weight is 1½ lb. It is priced $800.

A silicone-dampened, "hydrofluid," ball-leveling pan and tilthead tripod has been announced by National Cine Equipment, Inc., 209 W. 48 St., New York 36. It is suitable for use with all cameras weighing less than 40 lb. It features a telescopic pan handle with variable angle adjustment and can be operated from a righthand or lefthand position. It is priced at $329.50.



A new zoom bench, designed to speed up the production time for special effects, has been announced by Eastern Effects, Inc., 333 W. 52 St., New York 19. The machine is said to have the ability to reduce or enlarge a frame 20 diameters while maintaining automatic self-focus and aperture. It has even distribution of the light source in the field and is designed to spin a scene 360° while running live footage without use of prisms.

The Type 1830 Two-Film Adaptation Unit for use with the Arriflex 16mm camera is a product of the G. B-Kalee Division of Rank Precision Industries Ltd., 37-41 Mortimer St., London W.1, Eng. The new unit is used with the Gaumont-Kalee Single-System Magnetic Recording Unit to convert the single system into a two-film system suitable for indoor filming and sound recording. The new Two-Film Unit comprises a small box weighing 4¾ lb which contains a synchronous motor drive with gearing, film spooling plates, film footage counter and control switching. The Gaumont-Kalee Type 1690 soundhead is fitted into this unit, instead of to the picture camera as in the single system. Threading follows a straightforward pattern and the 3-position switch provides a choice of either local or remote operation.

A new 35mm Angenieux Zoom Kine Lens has been announced by James A. Sinclair & Co., 3 Whitehall, London, S.W.1. Dimension of the lens is 5½ by 2½ in. The aperture is *f*/3.5 and focal range from 35mm to 140mm. It is priced at $275.

The F & B Triplex Animation Stand, a product of Florman & Babb, Inc., 68 W. 45 St., New York 36, is described in a booklet available upon request from the company. The basic stand consists of two ground-steel columns, two inches in diameter, on which the camera carriage travels on ball bearings. A zoom hand wheel elevates the camera carriage. The columns pivot from a vertical to a horizontal position on a diameter axis of 1¾ in. which is fastened to cast-iron legs. The machine rests on four adjustable leveling feet. The artwork table has a 9½ by 12½ cutout for rear lighting. It is on an independent pivot, free from the columns so that the columns may be swung in an angular position and the table will remain level. The columns may be swung in a horizontal position and the table pivoted out of the way to allow photographing artwork of unlimited size. Height of the stand in the vertical position is 97 in. The length is 102 in. and the width is 36 in., and weight is about 450 lb. The basic stand is priced at $995.

An underwater blimp, tested by Navy Frogmen for one hour at a depth of 300 ft without pressurization, has been announced by Birns & Sawyer Cine Equipment Co., 6424 Santa Monica Blvd., Hollywood 38. The unit will accept either 16mm or 35mm Arriflex camera. It has a loading capacity of 400 ft. The 16mm Arri housing has separate nose cones available for the wider 5.7mm lens and accepts either 9mm Kinetal or 10mm Schneider lens. In the 35mm housing the sportsfinder will extend for 18mm lens use. For through-the-lens viewing, the cameraman has the same optical axis for lens and sportsfinder.

The Kodak Zoom 8 Camera (Automatic *f*/1.9) features a zoom (variable focal length) lens that in effect shrinks and stretches the camera-to-subject distance as it slides forward and backward. Recommended for amateur use, the camera can be set at the wide-angle (9mm), normal (13mm) or telephoto (24mm) positions. Under average daylight conditions, the wide-angle lens setting can be used as close as two feet from the subject; the normal lens setting to 3½ ft and the telephoto lens setting to 11 ft. The camera is priced at $139.50.

The Gaumont-Kalee Flutter Meter Type 1740, a product of Rank Precision Industries, is distributed in the United States by Benjamin Berg Co., 1410 N. Van Ness Ave., Hollywood 28. The flutter meter is designed primarily to measure the variations from constant speed of sound recorders or reproducers. It is equally suitable for use with machines employing photographic or magnetic soundtracks on film, tape, wire or disc records. The circuit comprises a tuned input amplifier which is also used as an oscillator, an amplitude limiter and a frequency discriminator. The frequency discriminator output is coupled to the "peak wow" meter. A Travis double-tuned discriminator is used. To provide for making measurements of machines which are not running exactly at the correct speed or from recordings in which the 3000 cps tone is only approximate, provision has been made for tuning the discriminator over the range 2850 to 3150 cps (±5% of mean). The tuning knob is on the front panel, with a scale marked in percentages above and below mean speed.

A portable, wide-range (2.5 cps – 25 kc) Sound and Vibration Analyzer, Type 1554-A, is a product of General Radio Co., West Concord, Mass. The instrument has 10:1 span on each of four ranges and features a ⅓-octave bandwidth (1.26:1), narrow bandwidth (8%, constant with frequency) and all-pass response. The analyzer is a tunable voltmeter, the bandwidth of which is a constant percentage of the center frequency. The miniaturized construction employs 11 transistors, four subminiature tubes and shock-mounted amplifier boards. It is contained

in a carrying case with overall dimensions of 10⅝ in. by 15⅜ in. by 11¼ in. It is priced at $1060.

The PS75 Stereo, a stereophonic version of the Magnecord P75 Editor tape recorder/reproducer is a product of Magnecord, Div. of Midwestern Instruments, Inc., P.O. Box 7186, Tulsa, Okla. It has stacked stereophonic heads and matched twin record/playback amplifiers. It is powered by a direct-drive dual-speed hysteresis synchronous motor and individual reel drive motors. The recorder features instant starting; automatic tape lifter for fast-forward and rewind; solenoid-operated fail-safe brake control to prevent tape spillage; automatic shutoff at the end of the reel, and easy manual cuing. Separate erase, low-impedance record and playback heads allow simultaneous record and playback. Price of the unit (without the case) is $1185. Supplied with a case, the price is $1305.

An all-transistor high-fidelity stereophonic amplifier and preamplifier called the TEC S-25 has been announced by Transis-Tronics (TEC), Inc., 1650 21st St., Santa Monica, Calif. The amplifier provides all possible sources for stereophonic FM multiplexing, AM sideband tuning and stereophonic TV. It is also adaptable to portable applications using either a 12-v d-c battery power supply or 115-v a-c house current. The system is recommended for a mobile home or boat.

A sound system which utilizes transistorized preamplifiers to maintain high-quality reproduction over long distances has been announced by Executone, Inc., 415 Lexington Ave., New York 17. One preamplifier is located adjacent to or built into each microphone, radio tuner and record player in the system. This preamplifier boosts the weak signal produced by voice or musical instrument and makes it strong enough to travel long distances to the power booster amplifier or mixer without noise pickup or other decrease in the quality of sound reproduction.

The FS Multi-Layer Interference Filter No. 6143, a colorless, nonabsorbing filter developed to remove completely ultraviolet while reflecting infrared, has been announced by Fish-Schurman Corp., 70 Portman Rd., New Rochelle, N.Y. The filter is said to transmit about 90% in the visible from 425μ to 700μ with a sharp cutoff beginning at 700μ, reflecting the longer wavelengths. The half-transmission point is at 412μ on the short side and 725μ on the long side.

A daily processing schedule for all 16mm black-and-white films has been announced by Fischer Photographic Laboratory, Inc., at its new headquarters at 6555 North Ave., Oak Park, Ill. The processing machines are designed and built by company personnel. The machines incorporate such features as developer temperature controlled to ±0.1 F, continuous replenishing and filtering of solutions and hypo silver recovery.

Commercial processing of the new 16mm Eastman High Speed color films, SO-260 Daylight (ASA 160), and SO-270 Tungsten (ASA 125) under license from Eastman Kodak Co. has been announced by Jamieson Film Co., 3825 Bryan St., Dallas 4, Tex. A newly-developed machine is used in the processing. Features include an unusual threading method and a system of drive which adjusts itself to the tension or slack condition of the film in process to prevent breaking. Chemicals may be completely exchanged every 20 minutes to insure uniform control of the process. The machine uses polystyrene tube-tanks through which the film is continuously driven. In addition to ordinary processing the firm is also offering forced processing to ASA ratings of 320 daylight and 250 tungsten, by special arrangement.

An agreement between Loew's, Inc. and Cinerama, Inc. for the production of dramatic feature-length films in the Cinerama process has been announced jointly by Joseph R. Vogel, President of Loew's, and Hazard E. Reeves, President of Cinerama. A series of "big-scale dramatic stories and musical comedy entertainment" is scheduled for production by Metro-Goldwyn-Mayer during the next seven years. Two versions of the three-strip films will be made, one for showing in theaters adapted to Cinerama and the other for eventual conversion to 35mm for world-wide release in conventional theaters. The Cinerama process was developed by Fred Waller and introduced to the public in 1952, but despite immediate public acceptance, it has been used in only five pictures and these are described as "glorified travelogues."

Special features of Cinerama include use of three projectors to produce a "natural vision" picture on a deeply curved wide screen. According to an article in the *Weekly Variety* of Dec. 23, 1959, the use of M-G-M's Camera 65 Panavision system in photographing Cinerama productions is being considered.

The Super-Technirama-70 process, first used in the production *Solomon and Sheba*, had its world premiere at the Astoria Theatre in London. The theater's Todd-AO screen was replaced by a larger screen with the curvature specially designed to afford an equally satisfactory view from each of the theater's 1400 seats. The new process uses standard Technirama 70mm prints projected under "super" conditions. The negatives, both picture and sound, are on 35mm. The picture is on horizontally-running Technicolor with a 1.5:1 squeeze effected by an anamorphic device designed for Technicolor by Prof. Dr. A. Bouwers of Holland. The device consists of an arrangement of glass prisms and mirrors which compresses the wide panoramic view sideways before recording it on the wide negative frame.

The projectors are a development of the type designed by Philips of Eindhoven, Holland, and are constructed with the

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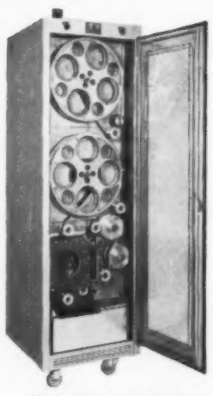

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greatest possible precision. In New York, Capitol Theater has been re-equipped for the first showing in the United States of *Solomon and Sheba.*

An experimental ground station for sending and receiving telephone messages by way of man-made satellites is being constructed by Bell Telephone Laboratories at Holmdel, N.J. The station will include control buildings and two large antennas for communication with objects in outer space. One of the uses of the installation will be to take part in communication projects sponsored by the National Aeronautics and Space Administration. Although single telephone channels will be used in the experiment, the objective is to determine whether television's broadband signals could also be transmitted. The microwave radio signals to be used in the experiment will be analyzed to obtain information about transmission effects. The data will also be studied to discover the reflection characteristics of satellites in orbit. The installation will include a dish-shaped antenna to transmit signals and a horn-shaped antenna, designed earlier by Bell Telephone engineers, to receive signals.

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employment service

These notices are published for the service of the membership and the field. They are inserted three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Motion Picture Laboratory Specialist. Well versed in equipment and procedures. Desires position with a well established organization. For resume write: Charles Stephens, 772 Miami Chapel Rd., Dayton, Ohio.

Director, Cameraman, Editor of nontheatrical films. Experienced in all phases of film production. Was employed by Audio Visual Service USOM/L, c/o American Embassy in Beirut, Lebanon as Program Advisor, Film Production Supervisor. Age 26, married, member of SMPTE, willing to relocate. Resume on request. Write: Hrayr Toukhanian, 3731 Irving St., San Francisco 22.

Motion-Picture Production and Direction. Former Secretary-Treasurer SMPTE Student Chapter CCNY, trained in all phases motion-picture production and directing, desires position with production company with possibility of working up through editing and camera to direction. Age 29, single, willing to relocate Robert F. de Brito, 120 East 31 St., New York 16. MU 5-3060.

Film Writer-Director-Editor with broad administrative, advertising and public relations background. Fully capable of supervising industrial audio-visual department. Screen credits include all types of films from documentary to drama. Know cost control, sound recording, evaluation, equipment. Write Film Director, 4410 Walsh St., Chevy Chase 15, Maryland.

Industrial Photographer, Producer, Director Desires position with vigorous film production outfit in either production or organization. Will accept heavy project responsibility. Experienced in all phases of motion-picture production and laboratory operations. Thoroughly familiar with military photographic requirements especially in the area of missile R & D. Single, willing to relocate. Resume on request. Write: Avrum M. Fine, 272 West 17th St., Hialeah, Fla.

Cameraman Trainee. Young Nigerian wishes to be trained as TV or motion-picture cameraman. Six years local training in Nigeria as projectionist-technician plus 2 yrs work and study in same field with C.M.A. Ltd., London. Practical experience in operation and maintenance of 16 & 35mm films and projectors. Serious student of film since age 15—now 24. Currently employed but anxious to train for a position where ability, sincere interest and creativeness offer opportunity. Will locate anywhere in U.S. Top industry and character references supplied in confidence. Sunny De Iseghohimen, Ministry of Research & Information, Film Production Unit, Ikoyi-Lagos, Nigeria.

Motion-Picture Technician. Just returned from 2 yrs work in Europe and Asia, including installation of motion-picture laboratory in Pakistan for Reevesound, Inc., and production management for Alfred Wagg Pictures. Formerly with Capital Film Laboratories, Washington, D.C., for several yrs; also designed and built production and lab equipment since 1945 under company name of Telex Films. Experienced to do capable work in production, editing, sound and laboratory. Particularly interested in overseas positions, will consider any part of the world. Complete resume on request. Victor E. Patterson, c/o Frank Enge, Jr., 1025 Connecticut Ave., N.W., Washington, D.C.

Positions Available

Technical Writers. Electronic equipment; familiarity with military specs and government procedure essential. Work in Long Island area. 12 required. **Electronic Engineers,** with TV camera, monitor, closed-circuit design experience. 15 required. Penult Corp., 103-14 Roosevelt Ave., Corona 68, N. Y. HIckory 6-1294.

Photographic Instrumentation Engineer. GS-13, $10,130 per yr. To act as technical rep. of U. S. Army Pictorial Center, N.Y., in working with manufacturers and reps. of other gov. agencies on testing, operation repair, design and supervision of manufacture of electromechanical instrumentation systems based on photographic recording devices. Considerable travel involved. Applicants must have 4 yr engineering college or equivalent college and experience combination, plus 3 yr general and 1 yr specialized engineering experience. Standard Form 57 (Application for Federal Employment), obtainable from the U. S. Civil Service Commission or any Post Office, should be completed and sent to: Civilian Personnel Office, Army Pictorial Center, 35-11 35th Ave., Long Island City 1, N.Y. RA 6-2000, Ext. 238.

Photographic Instrumentation. Los Angeles area firm manufacturing photographic instrumentation equipment needs a sales engineer. Engineering degree preferred. Position consists of selling, training field personnel, field service, and relating customers' requirements to the design of new products. Send resume to P.O. Box 22140, Los Angeles 22, Calif.

Laboratory Processing. Experienced or inexperienced processing man wanted by 16mm lab in Chicago area offering negative, positive, reversal and soundtrack developing. Write P.O. Box 401, West Chicago, Ill.

Motion-Picture Production. Organizers of new corporation in Managua, Nicaragua, require man well versed in professional motion-picture photography, with working knowledge sound recording, color, laboratory work, etc., to prepare budget of equipment necessary to start operating a motion-picture studio on an economical basis. Applicants should preferably be in a position to go to Managua to assist in the installation and operation of the studio, and in the selection and training of technical personnel. Send full information and salary requirements to: Conrad Morgan B., P.O. Box 1926, Managua, Nicaragua.

Cameraman. Prefer man with considerable experience on Mitchell Cameras. Midwest producer with fine reputation and financial standing wants man with ability and experience in lighting sets and operating camera on all kinds of interior and exterior photographic assignments. Very little travel involved in job. Excellent starting salary and opportunity. Write giving full details of past and present employment, equipment used, positions held, etc. Technisonic Studios, Inc., 1201 Brentwood Blvd., St. Louis 17, Mo.

Sales Engineer. Opportunity with West Coast office for sales engineer with manufacturer of theatre lighting and control equipment and architectural incandescent lighting. Work requires ability to call on architects, theatres, consulting electrical engineers, contractors. Location: in and around Los Angeles area. Please forward complete information, which will be kept in strict confidence, to: Century Lighting, Inc., 1840 Berkeley St., Santa Monica, Calif.

Photographer-Editor. Studio in Dallas, Texas, requires qualified motion-picture photographer and editor. Prefer college training. Please furnish references along with resume and salary requirements to: Keitz & Herndon, 3601 Oak Grove, Dallas 4, Texas.

Photographic Equipment Engineer. Excellent opportunity for photo engineer with thorough experience in determining special equipment needs for large photo lab operations, and executing the design specifications thereof. Will act as the authority on systems modifications and additions. Should have knowledge of printing equipment, processing and sensitometry. Write W. F. Marquette, RCA Service Co., Mail Unit 114, Patrick Air Force Base, Florida.

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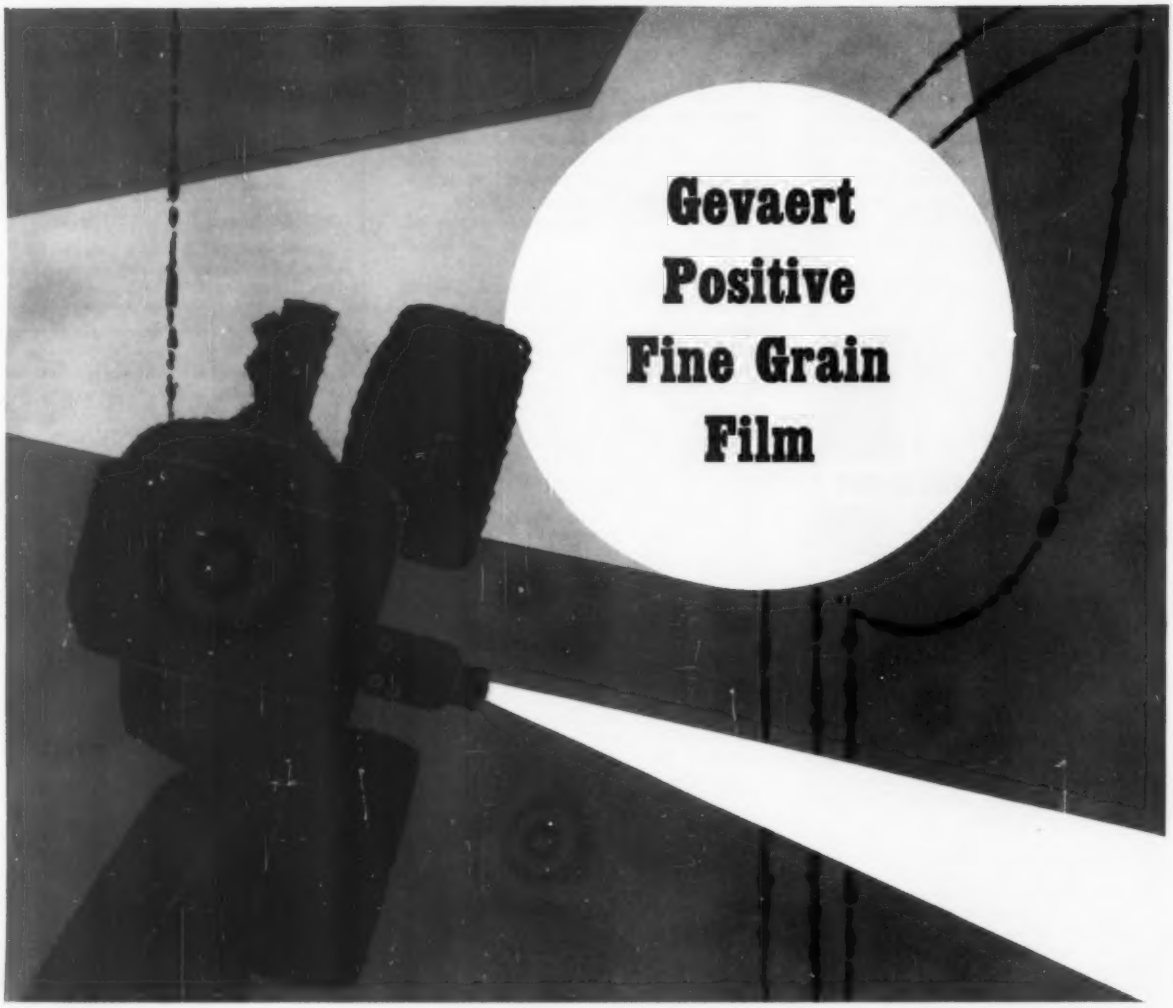

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AIEE, Winter General Meeting, Jan. 31–Feb. 5, New York.

IRE and AIEE, Transistor and Solid State Circuits Conference, Feb. 11, 12, 1960, Univ. of Penn., Philadelphia.

National Society of Professional Engineers, Winter Meeting, Feb. 18–20, 1960, Broadview Hotel, Wichita, Kan.

Deutsche Kinotechnische Gesellschaft, Annual Meeting and Equipment Exhibit, Mar. 1–5, 1960, Technical University, Berlin.

National Electrical Industries Show, Mar. 6–9, 1960, Coliseum, New York.

ASCE, New Orleans Convention, Mar. 7–11, 1960, Jung Hotel, New Orleans, La.

IRE National Convention, Mar. 21–24, 1960, Coliseum and Waldorf-Astoria Hotel, New York.

American Chemical Society, National Meeting, Apr. 5–14, 1960, Cleveland, Ohio.

Optical Society of America, Spring Meeting, Apr. 7–9, 1960, Hotel Statler, Washington, D.C.

Inter-Society Color Council, 29th Annual Meeting, Apr. 11, 12, 1960, Philadelphia Museum College of Art, Philadelphia.

IRE, South West Regional Conference and Electronics Show, Apr. 20–22, 1960, Shamrock-Hilton Hotel, Houston, Texas.

Manned Space Stations Symposium, Apr. 20–22, 1960, Ambassador Hotel, Los Angeles.

87th Semiannual Convention of the SMPTE, including Equipment Exhibit, May 1–7, 1960, Ambassador Hotel, Los Angeles.

IRE National Aeronautical Electronics Conference, May 2–4, 1960, Dayton, Ohio.

American Rocket Society, May 9–12, 1960, Ambassador Hotel, Los Angeles.

Society of Photographic Scientists and Engineers Annual Conference and Equipment Exhibit, May 9–13, 1960, Hotel Miramar, Santa Monica, Calif.

Society of Military Engineers, National Convention, May 16, 17, 1960, Washington, D.C.

ASME, Design Engineering Div. Conference, May 23, 1960, New York.

Design Engineering Show, May 23–26, 1960, Coliseum, New York.

Institute of the Aeronautical Sciences, National Summer Meeting, Mid-June, 1960, Los Angeles.

Acoustical Society of America, Spring Meeting, June 9–11, 1960, Providence, R.I.

National Society of Professional Engineers, Annual Meeting, June 9–11, 1960, Statler Hotel, Boston, Mass.

International Electronic, Nuclear and Cinematographic Exhibition, June 15–July 5, 1960, Rome, Italy.

AIEE, Summer General Meeting, June 19–24, 1960, Atlantic City, N.J.

American Society for Engineering Education, Annual Meeting, June 20–24, 1960, Purdue Univ., West Lafayette, Ind.

First Congress International Federation of Automatic Control, June 25–July 9, 1960, Moscow, U.S.S.R.

American Society for Testing Materials, Annual Meeting and Apparatus Exhibit, June 26–July 1, 1960, Chalfonte-Haddon Hall, Atlantic City, N.J.

AIEE, Pacific General Meeting, Aug. 8–12, 1960, San Diego, Calif.

European Conference on Electron Microscopy, Aug. 29–Sept. 3, 1960., Delft, Netherlands.

AIEE Fall General Meeting, Oct. 9–14, Chicago.

NEC National Electronics Conference, Oct. 10–12, 1960, Hotel Sherman, Chicago.

Fifth International High-Speed Congress and Equipment Exhibit, sponsored by the SMPTE, Oct. 16–22, 1960, Sheraton-Park Hotel, Washington, D.C.

Symposium on Space Navigation, Oct. 19–21, 1960, Columbus, Ohio.

89th Semiannual Convention of the SMPTE, May 7–12, 1961, King Edward Sheraton, Toronto.

90th Semiannual Convention of the SMPTE, Oct. 2–6, 1961, Lake Placid, N.Y.

91st Semiannual Convention of the SMPTE, Apr. 30-May 4, 1962, Ambassador Hotel, Los Angeles.

92nd Semiannual Convention of the SMPTE, Oct. 22–26, 1962, Drake Hotel, Chicago.

SMPTE Officers and Committees: The rosters of the Officers of the Society, its Sections, Subsections and Chapters, and of the Committee Chairmen and Members were published in the April 1959 Journal.

sustaining members

of the Society of Motion Picture and Television Engineers

The objectives of the Society are:

- Advance in the theory and practice of engineering in motion pictures, television and the allied arts and sciences;
- Standardization of equipment and practices employed therein;
- Maintenance of high professional standing among its members;
- Guidance of students and the attainment of high standards of education;
- Dissemination of scientific knowledge by publication.

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The Society invites applications for Sustaining Membership from other interested companies. Information may be obtained from the Chairman of the Sustaining Membership Committee, Byron Roudabush, c/o Byron Motion Pictures, Inc., 1226 Wisconsin Ave., N.W., Washington 7, D.C.